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MINERS' AND ASSAYERS' TEXT-BOOK,

ADAPTED TO THE

LABORATORY AND SCHOOL.

PRACTICAL INSTRUCTIONS TO ASSAYERS,
MINERS AND PROSPECTORS.

TESTS AND ASSAYS

OF ALL THE

PRINCIPAL METAL-BEARING ROCKS,

INCLUDING

GOLD AND SILVER BULLION.

—BY—

J. H. FISK, M. E.,

ASSAYER AND ANALYTICAL CHEMIST.

PORTLAND, OREGON:
THE J. K. GILL CO., PUBLISHERS.
1898.

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The author is well qualified for the work he has undertaken, the past thirty years having been spent in actual practice of his profession; for ten years he was the only assayer in Portland, during which time he assayed $3,000,000 in gold bullion against the United States Mint without an error; he has visited all the great reduction works in this country, and thoroughly familiarized himself with all the modern methods of treating ores. His principal object throughout this work has been, not so much to introduce new methods, as to compile, quote and abbreviate from best authors, together with his own large experience, and to arrange it in such form that the study can be taken up in a systematic manner. The book is particularly adapted to those who wish to obtain a practical knowledge of assaying, having been divested of all extraneous matter and symbols. The work has been plainly and carefully prepared and is especially fitted for the requirements of the prospector, the assayer, and for use in the class room. Heretofore much difficulty has been experienced by the student, from the fact that he has had to dig his information out of much voluminous reading matter which needed many explanations. This book is particularly adapted to colleges and universities, the examples and exercises at the end of each chapter greatly facilitating the perfect mastery of its contents. It is in three parts, bound in one volume.

Part First gives particular instructions for the use of that delicate instrument, the Assay Balance; and also the Assay Furnace; Oxidizing and Reducing Reagents; Solvents and

Precipitants; An Article on the Assaying of Gold and Silver Bullion; The Humid Assay of Silver.

Part Second describes the Preparation of the Ore Sample; Weighing of the Charge; Assay of Litharge; Crucible Assay; Crucible Assay for Gold and Silver; Melting in a Crucible; Scorification; Laboratory Test of Extracting Gold by the Cyanide Process; Assay of Tin and Copper Ore; Also the Cyanide Process of Assaying Copper Ore; Assay of Lead; Determination of Iron in an Ore; Chromium; Determination of Manganese; Assay of Zinc Ores; Of Nickel and Cobalt Ores; Mercury; Assay of Arsenic; Assay of Antimony; Assay of Bismuth; Determination of Sulphur; Assay of Platinum; Coal Analysis.

Part Three contains Notes of Instruction to those in Search of the Precious Metals; Firmness of Rocks; Constituents of Rocks; Metallic Ores Common in Rocks; Material of Organic Origin, including a Synopsis of the following rare Metals: Barium, Calcium, Chromium, Cerium, Lanthanium, Didymium, Columbium, Glueinium, Gallium, Indium, Iridium, Lithium Rudidium, Osmium, Palladadium, Tantalium, Tellurium, Thorium, Thallium, Vanadium, Yettrium, Zicronium, and the ores from which they are extracted. Glossary of 125 of the most important Minerals; Preliminary Examination of Ores, including Diaphaniety, Lustre, Color, Specific Gravity, etc.; Preparation of Pure Gold, Silver, and Lead; Table of Hardness and Specific Gravity of 25 Minerals; Blank for Mineral Analysis; Tables for the Calculation of Gold and Silver,

both by Gramme and Grains, also by the Assay Ton; Table for Computing Miner's Inches of Water; Calculation of Lead Blast Furnace Charges; Working Test of Gold and Silver Ores; Extracting Copper by Chloridizing; Making Silver Amalgam, and much other useful data.

Price 2.50 Postage Paid.

Orders for this work will be filled by the publishers or author, at Portland, Oregon.

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ERRATA.

Page 26. Third line from top read Symbol (Na. CO_3).
Page 35. Exercises No. 21 read Metallic Aluminum.
Page 105. Exercises No. 25 read rang, swing and rest.
Page 105. Exercises No. 28 read turns black.
Page 216 No. 9 read Titanium, not Fitanium.
Page 197. No. 1, 2 and 3 read alloys.
Page 102. Six lines from top read bumping, not lumbing.
Page 216. The symbols should be capitols.
Page 126. Third line from bottom of page, read experiment.
Page 52. Under Silver value, read 7¼ cents.
Page 253. Last paragraph is a repetition.

PREFACE.

Among the many valuable works on assaying anl testing of the metal-bearing rocks, I am not aware of one, having for its special object to explain and render simple to the beginner the various processes employed in assaying and determining the metals quantitatively, which has been devised for the illustration of the principles of the science.

Most of the works I have met with on technical laboratory work contain too many methods and much that is superfluous which tends to confuse the general student who has but a limited time to devote to the subject; while they are wanting in those explanatory details, without which he must often fail to understand the reason of the operation he is conducting.

In my long course of some thirty years of varied analytical practice and teaching, I have often felt the want of a collection of the most improved methods of quantitative determination of the different metals in an ore, and it is my wish to supply this deficiency, and at the same time to furnish a text for my own class as well as for the public schools where young men and women of the Northwest can obtain a theoretical knowledge of one of the greatest industries of the country. It is no less valuable to the assayer, the miner and the prospector, or to those who have made but little progress in the science; all will find in it information for their guidance.

My endeavor throughout has been to make everything as simple, plain, and practical as possible, and while the methods I have adopted may not prove superior to some others, they are as good as any yet placed before the people.

In offering this work to the public, I have no expectation of its being found faultless; but hope, from the care with which the manuscript was prepared, and rigorous comparison with the original source, that but few errors have crept in, and that the book will prove of value to both school and laboratory.

ABBREVIATIONS.

B. B.	Before the Blowpipe.
S. P.	Specific Gravity.
O. F.	Oxidizing Flame.
R. F.	Reducing Flame.
A. T.	Assay Ton.
Gr.	Grains.
Gm.	Grammes.
H.	Hardness.
C. P.	Chemically Pure.
P. P.	Precipitate.
C.	Centigrade.
F.	Farenheit.
Fl.	Flame Color.
On Ch.	On Charcoal.

CHAPTER I.

INTRODUCTION.

There are many well informed people who suppose that the earth consists of one hetrogeneous mass in which sand, clay, gravel and a variety of rocks are blended together with no more regularity than the ingredients of a plum-pudding. They suppose that this was its original condition, and that the present physical features of the surface, its mountains, seas, lakes and valleys, its rocks and its gravel existed from the beginning of time as we now see them.

But no sooner do we begin to penetrate below the surface than new views open upon us. There are many districts in which it is impossible even to sink a well, or to open a quarry or repair a road, without discovering that the rocks are arranged in layers and succeed one another in regular order.

All the rocks of the earth's crust are divided according to their structure into classes. The stratified rocks and unstratified (or fragmentary). The former are arranged in layers. The latter are not. The former are produced by the agency of water, the latter by igneous agency or volcanic action. The former marks the period of rest in the world's history; the latter chronicles the convulsions upon the external crust of the earth.

Thus looking upon the earth as an organic unit, we may study its form, the rocks and minerals of which it is composed, and the manner in which these are arranged; in other words, its external form and internal structure, and the substances of which it is composed.

All the substances in nature are either simple or compound. A simple substance or body is one from which nothing different from itself can be extracted. Charcoal and Sulphur are elementary substances. Treat either as you may you can extract nothing from them but Charcoal or

Sulphur. Chalk and Flint are compound substances. By analyzing Chalk we can extract from it a metal called Calcium. By analyzing Flint we can extract from it a substance called Silicon. Yet sixty years ago no one knew any difference, all were supposed to be simple or elementary substances.

There are now about seventy simple substances known, and these elements have a tendency to combine one with another, forming compounds; this tendency is called affinity, The strength of these affinities differ in different elements, one for another under different conditions of temperature, pressure, electricity, etc.

Most of the elements are known, and all are believed to be capable of assuming the solid or gaseous state; some the liquid, depending upon temperature and pressure.

1. These elements may be mixed in any proportion, but they can only combine in fixed proportions. When elements combine they form a compound wholly different in appearance from the elements which composed it.

2. Two or more solids may combine to form a liquid or a gas. Two or more liquids or gases may form a solid etc. A knowledge of these compounds and their separation forms the basis of Chemistry.

3. All metals are elements; two or more of them fused together form alloys. Hydrogen, Oxygen, Nitrogen, Chlorine, Bromine, Iodine, Carbon, Sulphur, Selenium, Phosphorus, Boron, Silicon, are simple elements which enter into composition of the ores, fluxes, etc., which come under the notice of the assayer. But we must remember that these elements combine only in fixed proportions.

4. "The element lead (a metal) combines with the element oxygen (a gas) in the proportion of 103.56 parts by weight of lead to 8 parts by weight of oxygen, forming 111.56 parts of litharge. Lead combines with oxygen un-

der certain conditions in other proportions, but the resulting compounds are not litharge."

5. The assayer should make himself acquainted with the atomic weights of the most common elements. The atomic weight of carbon is 12, and of oxygen 16; one part of the former combines with two of the latter to form 44 parts of the gas called carbon dioxide. If the above is true, the same combination would take place if 6 parts of carbon were combined with 16 parts of oxygen, making 22 parts of carbon dioxide (a gas) or 3 of the former to 8 of the latter. Under the action of heat, the affinity of carbon for oxygen is greater than the affinity of lead for oxygen; hence if litharge and carbon are heated together, the carbon takes oxygen from the litharge and sets the lead free. But this action can only take place between definite proportions of the substances, as above stated.

6. If twice 111.56 grains of litharge, containing 16 grains of oxygen, be heated together with 6 grains of carbon, the carbon takes all the oxygen, forming 22 grains of carbonic acid gas (carbon dioxide) and the whole of the lead is set free; but if more litharge had been present, that additional portion would have remained unchanged.

By this we see that 6 grains of carbon reduces 223.12 grains of litharge, setting free 207.12 grains of lead. Or in other words 1 grain of carbon produces 34.52 grains of lead from litharge.

7. Other substances take oxygen from litharge under heat, in different but fixed proportions for each. Charcoal, flour, starch, etc., are impure carbon and each liberates a corresponding quantity of litharge. One grain of charcoal liberates about 30 grains of lead from a corresponding quantity of litharge. One grain of flour will liberate about 15 grains of lead from litharge. Gum, starch, sugar, etc., will each produce their respective amount of lead from

litharge, in proportion to the amount of carbon they contain.

8. Nitre (or saltpetre) is composed of nitrogen, oxygen and potassium; when heated with lead, it gives off its oxygen which combines with the lead and forms litharge in accordance with the law of definite proportion. If sulphur or carbon be present the oxygen will combine with them because its affinity is stronger for the two latter than it is for the lead.

9. Compounds can combine with compounds forming new compounds. Carbonate of soda or carbonate of potash when used in assaying are compounds of the metal elements sodium or potassium with oxygen and carbon dioxide. Quartz is a compound of silicon and oxygen. When quartz is fused with these alkaline carbonates, the latter is decomposed, not into its elements, but into carbonate dioxide which escapes with effervescence and the sodium or potassium oxide, which combines with the quartz—a compound with a compound—forming glass, (a slag); by this means quartz which is not fusible in any common furnace heat, is easily converted into a fusible slag.

10. Again, if you melt a piece of lead in a ladle or dish of any kind, you will notice that its surface is at once covered with a scum; remove it by scraping it off with a stick and it will instantly be coated again. Continue doing this until all the lead is thus changed into scum or litharge. This is merely the lead combining with the oxygen of the air and converting it into litharge. Or in other words, it is 8 parts of oxygen combining with 103.56 parts of lead to form litharge. Gold and silver at an ordinary heat do not oxidize, but when gold, silver, and lead are melted together in the air in a bone-ash cupel, the lead passes off and is absorbed by the cupel, taking with it all the impurities from the gold and silver. This is the philosophy of cupellation.

11. Again if we place a strip of metallic silver in nitric

acid it manifests an affinity for a compound of nitrogen and oxygen which exists in the acid; gold does not, hence, when an alloy of gold and silver is boiled in nitric acid, the silver forms a compound known as nitrate of silver which can be crystallized and dissolved in water, but the gold will remain.

12. In obeying the law of combination in definite proportion it is necessary that we have acid present in sufficient quantity, otherwise a part of the silver will remain unaltered; if more acid than the required amount be used, the excess of acid will remain unchanged.

In practice, it is necessary in assaying bullion that the alloy contain at least twice as much silver as gold, otherwise the insoluble gold will so envelop the silver as to protect it from the action of the acid, leaving some silver in the gold, which would render the assay incorrect.

The art of assaying is dependent on the laws of chemistry, and may be practiced with considerable success, but can never be properly understood unless these laws are studied.

The table on the next page contains the names of thirty-six elements, because they are more frequently used than the others, and the only ones treated of in this book.

REFERENCE TABLE.

Symbol.	Quality.	Atomic Weight.	Strength.
	Negative end.		
O	Oxygen	16	2
S	Sulphur	32	2
N	Nitrogen	14	3
F	Fluorine	19	1
Cl	Chlorine	35.5	1
Br	Bromine	80	1
I	Iodine	127	1
CN	Cyanogen*	26	1
Se	Selenium	79	2
P	Phosphorus	31	5—(3)
As	Arsenicum	75	3—(5)
Cr	Cromium	52.5	2
B	Boron	11	3
C	Carbon	12	4—(2)
Sb	Antimony	122	3—(5)
Si	Silicon	28	4
H	HYDROGEN	1	1
Au	Gold	196.6	3—(1)
Pt	Platinum	197	4—(2)
Hg	Mercury	200	2 (Hg_2 a dyad)
Ag	Silver	108	1
Cu	Copper	63.5	2 (Cu_2 a dyad)
Bi	Bismuth	210	3
Sn	Tin	118	4—(2)
Pb	Lead	207	2—(4)
Co	Cobalt	59	2
Ni	Nickel	59	2
Fe	Iron	56	2 (Fe_2 a hexad)
Zn	Zinc	65	2
Mn	Manganese	55	2—(4)
Al	Aluminum	27.5	Al_2 a hexad.
Mg	Magnesium	24	2
Ca	Calcium	40	2
Sr	Strontium	87.5	2
Ba	Barium	137	2
Na	Sodium	23	1
K	Potassium	39	1
H N	Ammonium*	18	1
	Positive end.		

* Not elements.

For a further illustration on the art of assaying I cannot do better than quote from Aaron in his valuable little work; part first on gold and silver assaying:

"An assay is an operation performed on a known quantity of matter for the purpose of ascertaining how much of a certain substance that quantity of that kind of matter contains. A test is an operation performed on an indefinite quantity of matter in order to ascertain the character of that matter, or to determine the presence or absence of some particular substance. Thus, to test a piece of rock for silver is merely to try whether it contains any silver or not; to assay it for silver is to find out how much silver is contained in a weighed quantity, as an ounce or a half ounce, and thence, by calculation, in a ton of such rock. Testing may often precede assaying with great advantage because it enables us to know what kind of matter we have to deal with, and thus to adapt our method so as to insure a correct assay; or it may show us that an assay would be useless because of the adsence of the substance sought, or of its presence in such minute quantity only as to be practically worthless.

"To avoid confusion hereafter it is as well to mention that not only the act of assaying but also the definite quantity of matter operated on, is called an assay. Also, a test is either the act of testing, the thing tested, or the agent by means of which a test is made.

"Assays and tests are of two principal classes, the dry, or fire, and the wet, or humid assay or test. In the dry way the substance under examination is usually melted by heat, with the addition of such substances as may be necessary to produce fluidity and to separate the particular substance sought from the other components. The added substances are called fluxes, reducers, oxidizers, desulphurizers, etc., according to their functions in the operation. In the wet

way the substance, if solid, is acted on by means of liquid solvents such as acids, etc., which convert it, wholly or in part, into a liquid. By the addition of "reagents" to the liquid, the substance sought is separated, or its presence and in assays its quantity is determined by the occurrence of some appreciable phenomenon such as the production of a precipitate or of a color. For example, a portion of pure bullion is dissolved in nitric acid and a solution of common salt is added; the formation of a white precipitate indicates the presence of silver; this is a test. If the portion of bullion be weighed, and the exact quantity of salt required for the complete precipitation of the silver be also ascertained, the proportion of silver in the bullion is easily deduced; this is an assay. Again, a substance supposed to contain copper is dissolved in acid, and ammonia is added; the production of a blue color indicates that copper is present, and if the portion of the substance be weighed before being dissolved we can ascertain how much copper it contains by noting how much cyanide of potassium it takes to destroy the color.

"Silver ores are assayed in the dry way, gold ores by a combination of the dry and the wet way. By ores is here meant all mineral rock, or earth, containing the metal sought in small particles, or in chemical combination. Silver ores very frequently contain gold, and gold rarely occurs quite free from silver. The ore is ground to a powder, weighed, and melted in an earthen vessel (crucible or scorifier) with fluxes including lead in some form; a glassy mass (slag) and a lump of lead (button) result. The lead contains the precious metal, and is melted on a porous support (cupel) in an oven (muffle), converted into litharge and absorbed by the support. The gold and silver remain in the form of a bead on the support; the two are parted by boiling the bead in nitric acid."

EXERCISES.

1. What is the difference between mixing and combining?

2. In how many forms do the elements appear?

3. When two or more metals are fused together what is the result called?

4. In what proportion do lead and oxygen combine?

5. What are the combining weights of lead and oxygen?

6. By fusing 6 grains of carbon with litharge, how much lead is set free?

7. Name four substances that will reduce litharge to metallic lead.

8. When nitre is melted with lead, what is the effect?

9. What is the result when carbonate of soda and quartz are fused together?

10. What is the philosophy of converting lead into litharge?

11. What is the effect of boiling a strip of silver in nitric acid?

12. Explain the law of definite proportion.

The teacher should fully illustrate and explain each question.

CHAPTER II.

IMPLEMENTS.

It is of little use to describe and illustrate the different implements used in assaying, such as the various kinds of pulverizers, grinders, mortars, scales, muffles, furnaces, tongs, molds, scorifiers, crucibles, funnels, glassware, mattrasses, etc. How to use them can never be learned from books; nothing but the actual handling of them under the direction of a competent instructor will enable one to avoid their wholesale breakage and destruction. All these articles can be purchased of John Taylor & Co., 63 First street, San Francisco. To set a student to work without instruction in their manipulation would cost more in breakage than his tuition. There is a right and a wrong way to handle the implements in an assay office as well as in other professions. One ounce of practice is worth a pound of theory.

In addition to the foregoing the apparatus necessary for a well regulated assay office is extensive and expensive, and much of it has to be made up as the work calls for it, although it is necessary to keep quite a stock on hand of crucibles, scorifiers, cupels, casseroles, beakers, and funnels and an assortment of filtering paper, as well as pipettes and burettes, and flasks, together with the common stock of chemicals necessary for all kinds of work.

The following are indispensible: Shovels, pokers, scrapers, crucible tongs, scorifier tongs, cupeling tongs, cold-chisels and small anvil, spatulas, steel dies from 0 to 9 for marking bullion bars, cutting shears and nippers, an assortment of glass and rubber tubing, platinum wire and foil. Most of the apparatus used can be purchased of the dealers but with a little patience and practice a great deal of it can

be made in the laboratory. In purchasing apparatus and supplies, it is always cheaper in the end to buy the best.

It is not necessary that the student should memorize formulas, atomic weights, strength, etc. Let the pupil perform all the experiments he has a mind to, but not undertake the most difficult ones without assistance. This method takes time, but it is the only way to teach the use of the small flasks, test tubes, and small quantities of chemicals. Do not be afraid to teach anything contrary to the text if you have good authority for it, and let disputed points alone; teach any simple principal outside the text instead of more complex matter. Use the metric system. Use either thermometer, Centigrade (C) or Farenheit (F).

The following illustration will show an easy and convenient way and the other an awkward and clumsy way of doing work in simply pouring an assay into a mold.

THE NEW BEGINNER.

ONE WHO HAS LEARNED.

The above is a fair illustration of a thousand and one manipulations conducted in assaying and which can never be learned from books. While the student may read and study everything ever written on the subject, unless he has practical instructions in the handling and the use of the instruments, he will find himself conducting a very expensive business; for example: A few drops of cold water on a hot dish would cost him several dollars, besides ruining the results of his assay; a sudden heating or cooling of glassware in use would produce the same results. Or, the smallest particle of lead brought in contact with a platinum dish under heat would entail an expense of $5 to $10 in repairing the damage.

It is very important that the student should at once begin to make careful notes of all the experiments he engages in. He should endeavor to do this in as concise and methodical a manner as possible and he will find it very advantageous to make use of symbols in describing the substances he employs. and the changes whicr they undergo; he will thus be able to record much in a small space, and at the same time he will be making himself familiar with the composition of the substances with which he is experimenting.

The student will soon learn by experience that he cannot be too methodical in his operations, or too careful in cultivating habits of neatness and cleanliness.

It is not enough that the student should be able physically or mechanically to make up an assay charge of free-milling ore and assay it correctly; but he should know the reaction of each flux added and the function it performs. The public is already abundantly supplied with quack assayers, as well as quacks in other professions (and it is with more feelings of pity than censure that we admit it.) Such an one is he who would make an incorrect return for the purpose of pleasing his patron and encouraging him to spend

much time, labor, and money, in further development of his mine, only to find out at last that he has nothing; and a quack assayer of this kind deserves the severest censure.

I have often noticed that the newly-fledged assayer, who has merely learned how to assay a free-milling ore, is very proud of his achievement, priding himself on his superior knowledge, but he should not forget that there is always room for improvement, and not be so ready to condemn others who do not work in the same manner.

It would look better for such assayers to say less, and study more, for they might be called upon to check up with older and better-regulated establishments, on rebellious ores, when they would find themselves deficient in many things.

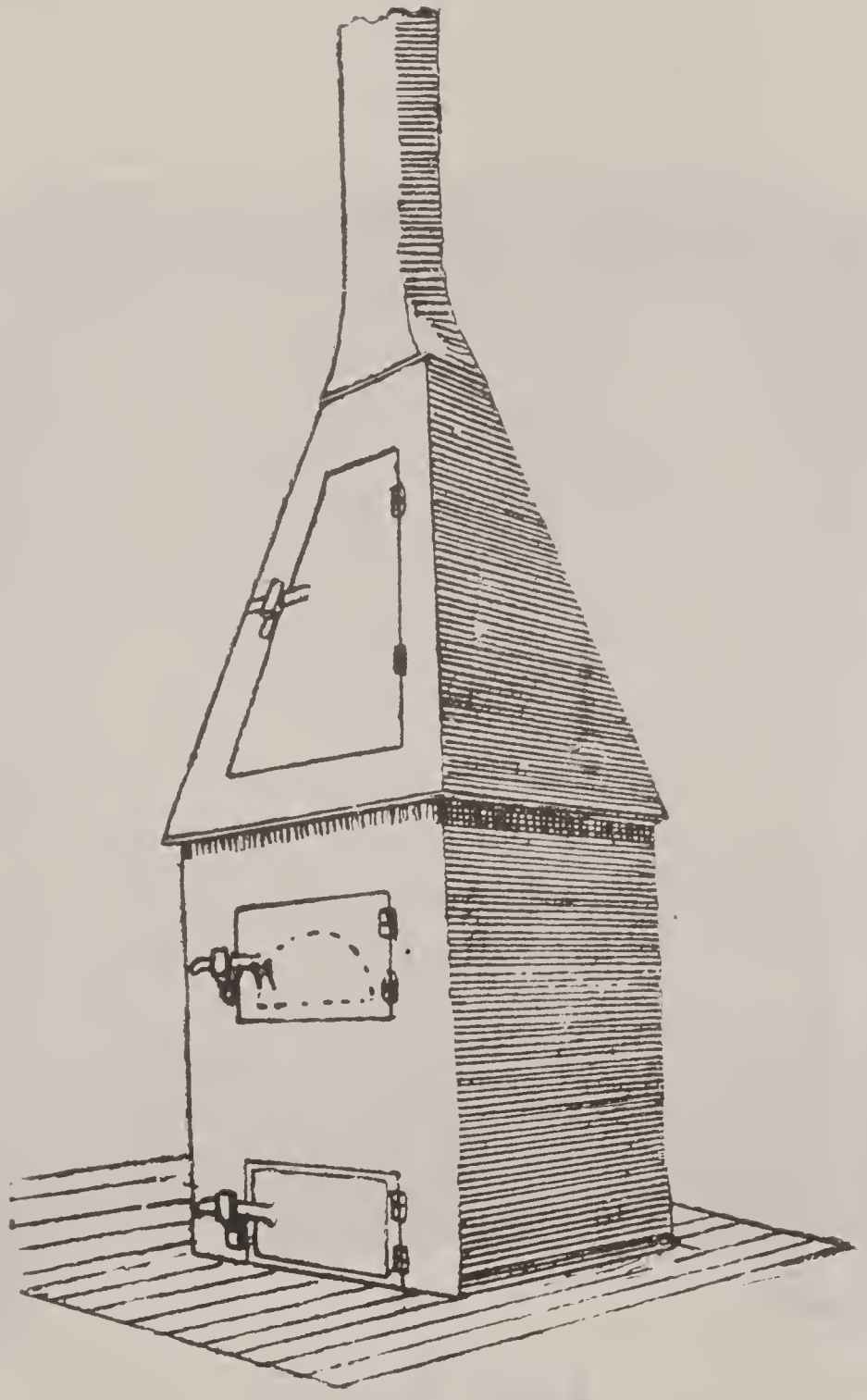
The art of assaying any and all kinds of ores is not so easy as many are led to believe.

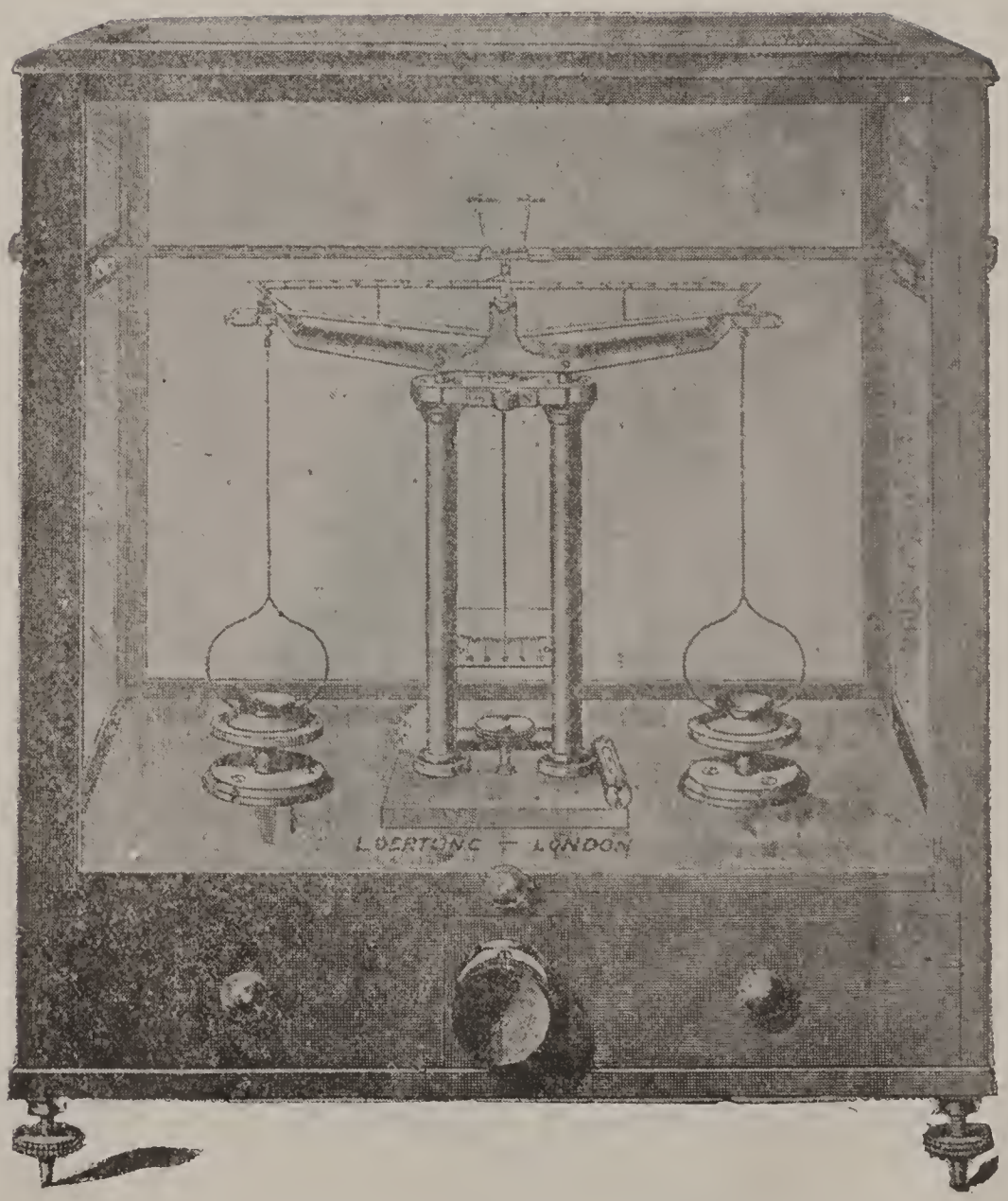
Every one who has been engaged in assaying and analytical work knows that cases will sometimes occur, especially in commencing the study, in which doubts may be entertained as to whether the results will turn out correctly. For instance, a small portion of the substance under investigation may be spilled, or the assayer may have doubts of the accuracy of his weighing; or he may not have sampled his ore correctly, or used the proper dressing for his assay charge; or got his numbers changed; or the charge in his crucible may boil over, causing a loss—all these things and a hundred more I might add are as much a part of the education of the assayer as the determination of the results.

In all such cases it is indispensable that the operator should throw away his blemished work and be conscientious enough to repeat the whole process over. He who is not possessed of this self-command; who shirks trouble where truth is at stake, who would be satisfied with mere guess-work where the attainment of positive certainty

is the object, must be pronounced a fraud. He, therefore, who cannot trust his work and cannot swear to the correctness of its results, had better occupy himself in some other avocation.

There are two very indispensable articles in assaying that need more than a passing notice; these are the assay furnace and the balances. In my varied practice I have used all kinds of assay furnaces, large and small. For small, ordinary work I have constructed a combination furnace which, for convenience and durability, I find excels all other coke and coal furnaces I have met with, and which I believe has been adopted by most of the assayers of the Northwest. It is portable with a hood which fits snugly down over the top and with a working door in the hood which carries off all the dirt and smoke. Its form is square and it need not be over 18 inches high, and nine and one-half inches square, inside measurement. It also has loose grate bars which greatly facilitate the cleaning process. Four assays can be melted at one time in it. For melting much gold dust in a plumbago crucible it is better to have the furnace 20 inches high. The Hoskins gasoline furnace is a very convenient and cleanly method of melting ores, as the gasoline can be had cheaply, and is quite a saving on muffles.





Assay Balance

CHAPTER III.

THE ASSAY BALANCE.

No reliable assayer will use a cheap grade balance, for while many of them may do for prospecting, etc., where reliable work is to be done for the public none but the very best should be used. The Ortling, No. 12, $175; No. 12 A, $225; No. 12 B, $175; and his best No. 12 C, $250, are all reliable and good balances. Beckers' No. 4, $135, is a fair balance. Troemners' No. 5, $175, is also a good balance.

I am told that the Ainsworth balance, manufactured in Denver, is a very fine one. There are many grades of prices and qualities of balances down to Troemners' No. 3 at $40; but after a little use I have found them wholly unreliable, for to the assayer the assay balance is the most important instrument of his whole outfit, being really what determines his results, and great care should be taken for their preservation and adjustment. The general public, however, knows very little about this instrument; nine out of ten would as implicitly trust their work to one of these cheap instruments as they would to the very best, although the results below $10 per ton are mere guesswork. A good balance should have a double sliding rod called a carrier, and should be furnished at its inner end with an arm extending at a right angle to the rod over the beam. On these arms hang the riders, each of known weight, so that when placed on the beam equal distances from the center, they will equally balance if otherwise properly adjusted.

By means of these carriers, operated from without the case, either of the riders can be placed upon the beam at any point desired, or removed at pleasure. The rider acts upon the principle of the pea on a steelyard, and is used to complete the weighing of an object on the balance without opening the case. The balance must be placed on a solid

table, or a shelf fastened to the wall of the building where no jarring of the premises can be felt. An open dish of quicklime should be kept in the balance case to absorb the moisture from the atmosphere.

The weights used with this balance are either grains or grammes corresponding with those used in weighing the ore for the assay. If in grains the set is from ten grains to one one-hundredth grain, or one one-thousandth of the ten grains. If in grammes, from one gramme to one milligramme. In either case the smaller is one one-thousandth part of the larger, and the system is the unit of one. The rider is used for smaller weighing of the fractions of these units, and must agree with the other weights of the set used, and with the number of divisions on the beam. In most cases the beam has five principal divisions on each arm and fifty subdivisions.

I doubt if any instruction can be properly given to a student for the adjustment of an assay balance without the practical illustration with the instrument itself, any more than can the repair or adjustment of a watch. Occasionally the balance may be dismounted and the parts cleaned with a soft chamois leather, and all dust removed from the beam with a camels' hair brush. One weight of the set should cause the index or pointer to swing one-tenth division from zero, and one-tenth obtained by the rider should cause a deviation of one division. The deviation should be the same on either side with the same excess of weight; if otherwise, the balance is a bad one.

I have known some assayers to make daily returns for years with an old and cheap balance full of dust and dirt, and which should never have been used at all. I may say here that no careful assayer would use such a balance, or his weights without testing them.

WEIGHTS AND WEIGHING.

I have had some difficulty in getting students to correctly set down their weights when weighing; they will frequently get the units and tenths of units mixed, placing the units where the hundredths should be, and the tenths of units where the units should be, and vice versa. To make it plain it is only necessary to remember that we are dealing with one thousand. For instance, in $10 there are 1000 cents, and in setting down our weights it is only necessary to place our dollars where our dollars should be, and the cents where the cents should be, and the mills where the mills should be, in the parts per thousand, and these are our assay weights.

The weighing of a bead or piece of precious metal obtained by an assay is "reported" in units of the set, not in grains or grammes. Thus, a bead weighing 1.145 grains is reported as 114.5; one weighing 0.0445 grammes is reported 44.5. One gramme or ten grains is therefore called 1000. An assay is simply a question of the proportionate weight of precious metal as compared with the weight of the ore from which it was extracted; and the weights used in weighing the ore for the assay must accord with those used in weighing the metal obtained. The proportion once ascertained, it is easy to deduce the absolute quantity of metal in a ton.

The 1000 assay weights should equal the 400, 300, 200, and 100 assay weights together; the 400 should equal the 300 and 100; and so on down the whole set of weights. It is not important that the weights should absolutely be standard, but they should be correctly proportioned one to the other.

CHAPTER IV.

REAGENTS.

1. The following are the principal fluxes used in dry or fire assays:

Sodium bicarbonate ($NaHCO_3$)—carbonate of potassium will answer the same purpose—acts as a desulphurizing agent or basic flux, and in some cases as oxidizing agent. It should be free from moisture and dried in a clean pan before using. It fluxes quartz rock, desulphurizes galena and some other sulphurets. Mix some powdered quartz with thrice its weight of soda, heat to a bright redness in a crucible; the result will be glass when poured out.

2. Borax, $2NaBO_2$, B_2O_3, $10H_2O$. To prepare for use.—Heat it gently in an iron pan until it swells no more, then cool and grind it; it should not be melted, as that makes it hard to grind. Borax may be bought already ground, and may be used in this way without drying. It fluxes clay, lime, magnesia, slate, etc., and metal oxides generally; also quartz, but not so well as soda. Borax glass is made by melting in a clean crucible cast in thin plates on a flat iron, then grinding to powder; one part by weight is equal to two of undried borax, and does not swell.

3. Litharge (PbO)—Lead Oxide. It fluxes most rocks, earths, and metal oxides, and is very destructive to crucibles if used in excess, for which reason other substances, to a certain extent, are used in place of it. It is an oxidizer because it gives up its oxygen to combustible substances, causing them to burn or become oxidized; it thus burns sulphurets in an assay, and although all the substances are not burnt out, their conditions are changed and converted into their respective products of combustion. It is a desulphurizer because it burns the sulphur of sulphurets, as well as oxidizing its metals, except lead and the noble

metals; is a source of lead in the assay by giving up its oxygen, leaving the lead in a metallic state.

4. Glass, (S_2O_2) common bottle or window—Acts like borax but harder to melt. Used in an assay when it contains much lime or clay but not with quartz. Useful in an assay when much nitre or litharge is used. It is an acid flux.

5. Lead Flux.—A mixture of 16 parts of bicarbonate of soda and 16 parts of carbonate of potash, 4 parts of flour, and 8 parts of borax glass is an old lead flux and a good one, because it is both a reducing and a desulphurizing agent.

6. Black Flux consists of one part of nitre and three parts of argol (deflagrated). This is an old flux recommended by Mitchell, but it is not much used now, and with all the other modern fluxes it is superfluous.

7. Nitre or Saltpetre (KNO_3) is a powerful oxidizer, then a flux and a desulphurizer. When fused gives off large quantities of oxygen, leaving the potash as a flux the same as soda. Nitre oxidizes all metals except gold and platinum; used to counteract the effect of too great a quantity of sulphurets in an assay, which it does by burnig a part of them which would otherwise produce too much lead from the litharge. To determine the oxidizing power make up the following charge, place it in a clay crucible and fuse in a hot fire. Remove, pour, cool, and weigh the lead button. The difference between the weight of the lead button obtained and that given in the determination of the reducing power of charcoal divided by 1.5 gives the oxidizing power of nitre per gramme:

Charge—Litharge	30	grammes,
Soda Bicarb....	15	grammes,
Charcoal	0.5	grammes,
Nitre	1.5	grammes.

8. Sulphur—Used in a certain class of assays in certain cases to prevent copper from entering the lead button, which it does by converting the copper into a sulphuret; but no instructions can be given as to what kind of copper ores it should be used in. It must be left to the intelligence of the assayer alone.

9. Iron (Nails) is a good desulphurizer for galena and for compounds of silver with sulphur, but not for copper or zinc ores. It can take all the sulphur and arsenic from lead and silver ores, setting these metals free; but it can only take a part of the sulphur from iron and copper pyrites and some other sulphurets, leaving a part of the metals combined in the form of matte.

10. Potassium Cyanide (K C N) is a powerful reducing and desulphurizing agent. It is used for the determination of tin, bismuth, and sometimes antimony by fire assays, and for the wet assays of copper. It should be pure and free from sulphides and sulphates.

11. Argol (K H C_4 H_4 O_6). Commercial bitartate of potash. This is also a powerful reducing agent and a basic flux. Its reducing power should be determined by fusing with litharge and carbonate of soda.

12. Charcoal (C) acts as a reducing agent and a desulphurizer like flour, starch, sugar, etc., but their reducing power must be determined before using to know the amount of carbon they contain.

11. Salt (Na Cl) is used principally as a cover in crucible assays. Glass of borax is equally as good, washing the sides of the crucible. If mixed with the assay it tends to prevent overflowing by becoming fluid at a low temperature and facilitating the escape of gases.

14. Granulated Lead (Pb) acts as a basic flux and collector of the precious metals. Used in scorification assays in which the litharge required as a flux is produced from lead.

15. Sheet Lead must contain no gold or silver. Used in bullion assays for cupelling off the base metals.

All the above fluxes should be dry and pulverized and kept in their respective boxes with covers where they will not become contaminated.

EXERCISE.

1. What are the two principal fluxes used in fire assays?
2. For what is borax used in the fire assay?
3. For what is litharge used and what function does it perform?
4. What is the use of glass? In what kind of ores?
5. What is a good flux for a lead ore assay?
6. What is black flux?
7. State the use of nitre in an assay.
8. For what purpose, and in what class of ore assays is sulphur used?
9. What is the use of iron nails? In what kind of ores?
10. In what kind of ores is potassium cyanide used? Is it a reducer or desulphurizer or both?
11. What is argol? For what purpose is it used?
12. State the use of charcoal. What is the difference between charcoal and argol?
13. Mention the use of salt.
14. In what kind of ore assays is granulated lead used?
15. In what kind of assays is sheet lead used?

CHAPTER V.

SOLVENTS.

The following are the principal fluxes used in wet assays or chemical analyses and as solvents during fusion.

1. Carbonate of soda (No_2 CO_3) acts as a decomposing agent and is used for the decomposition by fusion, either alone or in conjuction with other reagents such as carbonate of potassium (K_2 CO_3) or nitrate of potash (K N O_3), A mixture of the two carbonates in porportion to their molecular weights is a most excellent flux for the decomposition of certain silicates, clays, etc., which are with difficulty decomposed by either carbonate alone. They should be pure and free from moisture.

2. Potassium bisulphate (K H S O_4). This is a decomposing agent as well as an acid flux. Silica is not rendered soluble by fusion with it, while iron oxides, alumina, etc., are converted into a form which is soluble.

3. Sodium hydrate (Na O H) acts both as a decomposing agent and a basic flux. It is used principally for the decomposition of sulphides and sulphates in the determination of sulphur. It is sometimes used for the decomposition of certain silicates.

4. Potassium hydrate (K O H) acts the same as sodium hydrate and is used for the same purpose.

5. Hydrofluoric acid (H Fl) is one of the most powerful decomposing agents. By it most of the silicates are decomposed and volatilized; it is kept in gutta percha bottles and must never be allowed to touch the hands as it makes a very bad sore.

6. Water (H_2O). Used in analyses for solution, dilution, etc. Should be pure distilled. Snow or ice water will do if filtered and clean.

7. Hydrochloric acid (H Cl). This acts as a powerful solvent, either alone or in conjunction with other acids.

Three parts of hydrochloric acid and one of notric acid form aqua regia, one of the most powerful solvents. It dissolves gold and platinum. Should be pure.

8. Nitric acid ($H\ N\ O_3$) is a powerful solvent and oxidizing agent. It should be pure and kept on hand in concentrated and dilute state. The specific gravity should be 1.2.

9. Sulphuric acid ($H_2\ S\ O_4$) is a great solvent and is extensively used both as a solvent and a precipitant. The specific gravity of the concentrated acid is 1.84. The dilute is prepared by adding one part by volume to five volumes of water.

10. Acetic ($HC_2\ H_3\ O_2$), Oxalic ($H_2\ C_2\ O_4$), Citric ($H_3\ C_6\ H_5\ O_7$, $H_2\ O$) and tartaric acids $H_2\ C_4\ H_4\ O_6$) are all weak solvents and are much used for special purposes. Acetic acid comes in solution C. P. The other acids come in crystalline form.

All these acids are best used in a chemically pure state—are marked C. P. In making up these solutions it is best to use an excess of the reagents, thus making a saturated solution.

11. Ammonium acetate ($NH_4\ C_2\ H_3\ O_2$) is a great solvent for lead salts, especially lead sulphate. The best method of making it is by adding strong acetic acid to strong ammonia water until the solution is just acid, and then adding a few drops of ammonia to render the solution alkaline.

12. Ammonia ($NH_4\ O\ H$) acts as a powerful solvent of the chlorides and bromides of silver.

13. Sodium hyposulphite ($Na_2\ H_2\ S_2\ O_4$) is a solvent of silver chlorite and is largely used in leaching of silver ores.

14. Potassium cyanide ($K\ C\ N$) is a solvent of gold and silver and is extensively used in extracting the gold from the ore.

15. Ammonium sulphide [$(NH_4)_2S$] is a powerful solvent of the sulphides of arsenic, antimony and tin.

EXERCISE ON SOLVENTS.

1. How is oxygen made, and for what is it used?
2. State the difference between potassium bisulphate and carbonate of soda as solvents.
3. What are the three uses of sodium hydrate?
4. What is the principal use of permanganate of potash?
5. How, and for what is hydrofluoric acid used?
7. For what is hydrochloric acid used? What is aqua regia?
8. Is nitric acid an oxidizer or a reducer?
9. For what is sulphuric acid used as a solvent, and what does it precipitate?
10. What is the use of acetic acid?
11. What is the use of ammonia acetate?
12. What are the uses of ammonia?
13. What is sodium hyphosulphite a solvent for?
14. What is potassium cyanide a solvent for?
15. What is ammonium sulphide a solvent for?

PRECIPITANTS.

There are a large number of precipitants used in wet assays of which only a few will be mentioned here.

1. Barium chloride ($BaCl_2$). Used as a precipitant for sulphuric acid. In making up the solution one gramme of the salt is added to 10 c.c. of water. One c.c. of this solution will precipitate 0.0327 grammes of SO_3.

2. Hydrodisodic phosphate (Na_2HPO_4). This is used principally to precipitate magnesia from ammonia solution. In making up the solution one gramme of the crystalline salt is added to 10 c.c. of water. One c.c. of this solution will precipitate 0.012 grammes of Mg. O.

3. Ammonium oxalate [$(NH_4)C_2O_4$] is used prin-

cipally as a precipitant for calcium. In making up the solution one gramme of the salt is added to 10 c.c. of water. One c.c. of this solution will precipitate 0.0145 grammes Ca O.

4. Magnesia mixture is used as a precipitant for phosphorus and arsenic. To make the solution take 1 gramme of Mg C O_4 (salt), 1 gramme of N H_4 Cl (salt), and 4 c.c. of ammonia and add to 8 c.c. of water. One c.c. of this solution will precipitate 0.024 grammes of P_2O_5.

5. Molybdate solution is also used as a precipitant for phosphorus and arsenic. In making up the solution 1 gramme Mo O3 is dissolved in 4 c.c. of ammonia and the solution is poured into 15 c.c. of H N O3—S. P. 1.2. One c.c. of this solution will precipitate 0.0013 grammes of P_2 O_5.

6. Silver nitrate (Ag N O3) is used principally as a precipitant for chlorine. To make up the solution 1 gramme of salt is added to 20 c.c. of water. One c.c. of this solution will precipitate 0.0104 grammes of Cl.

7. Potassium chlorate (K Cl O_3) is a great oxidizer used precipitant of Mn O_2, also in volumetric estimation of iron.

8. Ammonia (NH_4 OH) is used as a precipitant of iron, alumina, and is much used in laboratory work.

9. Ammonium carbonate [(N H_4) 2C O_3] is used to precipitate Zn, Mn, Fl, Ca, Ba, etc. To make the solution take 1 gramme of the salt and 1 c.c. of ammonia and add to 4 c.c. of water.

10. Ammonium sulphide [(N H4) $_2$S] is used as a precipitant of Fe, Z, Mn, Ni, and Co. To prepare the solution pass a strong current of pure sulphuretted hydrogen through two parts of ammonia, then add three parts of ammonia to it. Keep well corked and in a dark, cool place, as it loses strength.

11. Ammonium chloride (N H_4 Cl) is used with ammonia to precipitate iron.

12. Sodium carbonate (Na_2 Co_3) is used to precipitate Zn, Fe, Mn, Ca, Ba, etc. A saturated solution is best for use.

13. Sodium sulphide (Na_2 S) is used as a precipitant for the heavy metals and is a solvent for the sulphides of arsenic, antimony and tin. To prepare it add 1 gramme of the salt to 10 c.c. of water.

14, Sodium acetate (Na C_2 H_3 O_2) is used to precipitate iron and alumina in the basic-acetate separation of these metals.

15. Sodium chloride (Na Cl) is used to precipitate silver both in gravimetrical and volumetric determination.

16. Platinic chloride (Pt Cl_4) is used to precipitate potassium. To prepare it dissolve 1 gramme of the metal in aqua regia; evaporate to dryness, and dissolve in one c.c. H Cl and 9 c.c. of water. One gramme of this solution will precipitate 0.048 grammes of K_2 O.

17. Hydric sulphide or sulphuretted hydrogen (H_2 S). Used to precipitate all heavy metals. To prepare the gas add dilute sulphuric acid to iron sulphide, and wash the gas by passing it through the water.

18. Sulphuric acid (H_2 SO_4) is used to precipitate barium, lead, etc. One gramme of the dilute acid will precipitate 0.4291 grammes of Ba.

19. Metallic zinc (Zn) is used to precipitate Pb, Cu, As, Sb, Ag, and Au from cyanide solution. The zinc is used in the form of sheets or granulated zinc, but for precipitating gold from cyanide solution it should be in the form of zinc shavings, thus preventing a deposit on the zinc plates by forming a hydrogen film on the zinc.

20. Metallic copper (Cu) is used to precipitate mercury. Should be used in the form of thin foil and sheets.

21. Metallic aluminum (Al) is used to precipitate copper and bismuth. Should be used in the form of sheets or foil.

Pure material should always be used. In making up the solution the water must always be pure.

EXERCISES ON PRECIPITANTS.

1. For what is Ba Cl used as a precipitant?
2. How would you make up a solution of hydrodisodic phosphate?
3. For what is ammonium oxalate used as precipitant?
4. How is magnesia mixture made?
5. In what way is molybdate solution used?
6. How many grammes of chlorine will a c. c. of silver nitrate precipitate?
7. What is the use of potassium permanganate?
8. What is the use of ammonia?
9. How would you make a solution of ammonium carbonate?
10. How would you make a solution of ammonium sulphite?
11. For what is ammonium chloride used?
12. What will sodium carbonate precipitate?
13. What will dissolve arsenic, antimony, and tin?
14. What is the use of sodium acetate?
15. When is sodium chloride used?
16. How would you prepare a solution of platinic chloride?
17. For what is hydric sulphide used?
18. How much Ba will one gm. of dilute sulphuric acid precipitate?
19. In what form is metallic zinc used?
20. What will precipitate mercury?
21. What will metallic chromium precipitate?

CHAPTER VI.

REDUCING REAGENTS.

All of the following class of reagents have the power of removing oxygen from its compounds. They are the reverse of oxidizing reagents.

The principal reducing reagents used in the fire assays are argal, charcoal, flour, starch, sugar, potassium, ferrocyanide, and potassium cyanide already mentioned under the head of "Fluxes."

The following are the most important of the reducing reagents used in the wet analyses:

1. Hydrogen (H) is a most powerful reducing agent used in the form of gas the same as sulphuretted hydrogen. It is best prepared by treating zinc with dilute sulphuric acid.

2. Sulphuretted hydrogen (H_2S) is also a powerful reducing agent. The gas is prepared in the manner described under the head of precipetant.

3. Sodium sulphite ($Na_2\ SO_3$). This is a good reducing agent. Used for the reduction of ferric solutions. It separates arsenious sulphide, which is soluble in it, from the sulphides of antimony and tin which are insoluble in it.

4. Stannous chrolide ($Sn\ Cl_2$) is used for the reduction of iron solutions for the volumetric estimation of iron. It is also used for the detection of gold in solution by forming a purple color.

There are many other organic compounds, such as tartaric acid, sugar, etc., which will serve as reducing agents.

OXIDIZING REAGENTS.

The oxidizing reagents most often used in fire assaying are nitre, litharge, sodium bicarbonate, and oxide of iron.

The following are the principal oxidizing reagents used in wet analyses:

1. Oxygen (O) is a most powerful oxidizing agent, and is produced by using chlorate of potash and black oxide of manganese in an iron retort and conducting the gas into a bag.

2. Chlorine (Cl) is a great oxidizer and is generated by treating bleaching powder (chloride of lime) with sulphuric acid.

3. Bromine (Br) is a good oxidizing agent. It is purchased in liquid form. It must never be uncorked but a few moments as it will combine with the orygen of the air and fill the room with the gas. When used it is added to water and used as bromine water.

4. Potassium permanganate (K_2 Mn_2 O_8) is a powerful oxidizing agent, and is much used in volumetric analyses of iron and many other metals.

5. Potassium bichromate (K_2 Cr_2 O_7) is a powerful oxidizing agent largely used in volumetric analyses.

6. Nitric acid (H N O_3) is a very powerful and most convenient oxidizing agent. It is largely used for the oxidation of precipitates. Must always be used pure and kept in a dark place.

7. Potassium chlorate (K Cl O3) is a great oxidizer used for the manufacture of the gas, also in fusion and in solutions.

8. Sodium nitrate (Na N O_3). Used as oxidizing agent in fusion. The potassium salt (K N O_3) may be used for the same purpose as the sodium salt.

9. Ammonium nitrate (N H_4 N O_3) is a good oxidizer, and is easily decomposed when heated.

EXERCISE ON
REDUCING REAGENTS.

1. How is hydrogen manufactured?

2. What is the principal use of sulphuretted hydrogen gas?

3. What is the use of sodium sulphide?
4. What is the use and test of stannous chloride?

OXIDIZING REAGENTS.

1. How is oxygen prepared?
2. How is chlorine gas prepared?
3. In what way is bromine used?
4. What is the principal use of permanganate of potassium?
5. What is the principal use of potassium bichromate?
6. How should nitric acid be used?
7. For what is potassium chlorate used?
8. What is sodium nitrate used for?
9. What is ammonium nitrate used for?

CHAPTER VII.

MELTING OF GOLD AND SILVER BULLION.

For the determination of silver in silver bullion, or gold in gold bullion, the furnace and fuel may be the same. Coke or charcoal,or in some places stone coal, may be used. It should be free from dust and broken into small lumps the size of a hen's egg. Charcoal is best to start with .

1. The black lead crucibles and covers should first be annealed by drying them for a day in a good oven, or by placing them in a furnace after melting and letting them cool down with it. Then before using insert crucibles and covers over a good fire until they are red-hot; they are then ready for use and may be placed when cold in the hottest fire without danger of fracture, which is sure to be the case if not annealed as above described.

The metal to be melted, if in small quantities, may be put into the cold crucible (pot), then placed in the fire, resting on a piece of fire brick.

2. Small crucibles with small lots of gold dust may be set into the fire with fragments of coke placed around them to keep them upright, and then covered.

3. In melting large lots in large crucibles it is best to feed a part of the metal or gold dust with an iron scoop made for the purpose.

4. Borax is added, the pot covered, and fuel placed around it. Retorted amalgam, especially silver, is porous and bulky, and the pot must be filled from time to time as it is melted down; sometimes such metal contains quicksilver and then the addition must be made before that in the pot is quite melted; otherwise spurting may occur.

5. When the metal is all thoroughly melted and the slag formed by the borax floats thin on the surface, it must be removed. The skimmer is placed in contact with the slag to which it adheres. The skimmer is then withdrawn,

pressed on the surface plate and dampened with water to cool and flatten the adhering slag. Occasionally dip it in water slightly to cool it and again touch the slag, rolling it upon the furnace plate, and so on until the slag is completely removed from the surface of the metal. Replace the cover and in a few minutes it is ready to pour into the mold.

6. The slag must be neither too thin nor too pasty; if the latter it may contain globules of the metal, and if the former it cannot be readily skimmed off.

7. A small amount of bone ash may be used to thicken it . If too thick add a little borax. When all the slag has been skimmed off, the surface of the metal is bright, and it is ready for pouring.

8. If the surface is covered with a skum it probably contains copper, iron, or sulphur.

9. If rainbow colored rings are seen, it is owing to a small quantity of lead; if brilliant spots appear moving rapidly it shows that much lead is present. Therefore, follow closely these directions.

10. First. If too thick add a lump of borax to absorb the base metallic oxides and when melted skim it off. If this does not purify it sulphur is probably present.

Second. Add a mixture of borax, nitre, and pulverized glass; felt and then skim it off. If this treatment does not prove efficacious lead is probably present.

. Third. Then add some cupels, allowing them to float on the metal for ten or fifteen minutes; they will absorb the lead. If much copper is present it is best to let it remain with the bullion in the bar, as it will make no difference in the determination of the silver or gold except that it will make it much harder.

11. In melting gold and silver together or in melting gold dust alone it is important that the metals be well mixed. For this purpose the stirrer is used—a strip sawed

from an old plumbago crucible will do. While the melting is in progress the stirrer is heated to redness and the metal thoroughly stirred before pouring into the mold; especial attention must be paid to this if the metal is of any considerable quantity. With a small lot of forty or fifty ounces it is unimportant, as it can be easily mixed by surging it around in the pot by the tongs.

13. For casting large lots in the mold, it is important that it be thoroughly smoked by mounting upon two brickbats over a dish of burning rosin until the mold is well coated with soot; this insures a smooth bar if the mold is just merely warmed. In casting small bars of thirty to fifty ounces mere oiling of the mold is sufficient.

14. In all cases to have a good cast it is necessary that the pour be continuous from the commencement to the finish.

15. Sprinkle some charcoal powder on to the metal as soon as poured to burn off any oxides of iron and to prevent silver from oxidizing.

16. When the bar is sufficiently cooled it is turned out of the mold, cooled in water, scoured, smoothed, if necessary, by hammering, and dried by warming it on the furnace cover; this is necessary, for a one-hundred ounce bar will absorb a penny weight of water in cooling.

17. The bar is now ready for weighing and chipping. The chips are taken from two diagonally opposite corners, one top and one bottom. The chisel is held between the thumb and fingers of the left hand so as to retain the chip.

18. If the metal is malleable the chip can be taken in one piece, flattened on the anvil, then rolled out, cut in small pieces with the scissors for weighing. If the metal is brittle it is best to cut it in several small pieces to facilitate the weighing of the assay, and each sample placed on a separate piece of paper.

19. The number of the deposit is marked on the paper.

20. One assay is made from each sample and if the two do not agree, and the third assay or "control" does not correct the result, the bar is melted over and remixed. The sample must be large enough to allow several assays to be made of each, the residue being folded up in the paper with the number of the deposit marked thereon and kept for future reference.

21. Each bar is finally stamped on the face, which was the bottom of the bar when cast, with the name and address of the assayer, the weight in troy ounces and hundredths, with the fineness, and the value in gold, or in both gold and silver, according to the character of the bullion.

22. When gold predominates and is above 500 fine in that metal it is called a gold bar; when silver predominates and is above 500 in silver then it is termed a silver bar, and is stamped for both gold and silver.

On delivery it is accompanied by a certificate stating the number of the deposit, the name of the depositor, the weight both before and after melting, the fineness, value in dollars and cents, charges, etc. Any globules which may remain in the pot, may be weighed together with the chips and added to the bar, and the value recovered according to the assay.

23. The value stamped on the bar is the assay value. But the commercial value depends upon the market price for that description of bullion.

A black lead pot should not be used more than four or five times with any considerable quantity of metal, as it is liable to part at the surface of the metal, spilling the metal into the grate and ash pit below. In this case the furnace must be opened and the fire left to die down and cooled. Then the metal may be recovered by washing the ashes and cinders.

24. It is often that the assayer has to treat small lots of base bullion or gold scrapings from plates. In such cases it can be refined by cupellation. A large cupel can be made with a large mold or sometimes the moistened bone ash can be packed into a roasting dish or in the bottom of an old crucible with holes drilled through it. When well dried and required for use it may be placed on the coals in the melting furnace, or better in the muffel if there is room for it. Add some lead to it and when that is melted add the impure gold and silver, and proceed with the cupellation as in other cases.

An iron or tin ring or hoop can be used to make a large cupel by forcing the dampened bone ash into it and leaving it to dry. Use with the ring still on it.

EXERCISE.

1. How should a black lead crucible be treated before using?
2. How would you melt small lots of gold or silver, say 10 or 50 ounces?
3. How would you treat large lots, say 40 or 50 pounds?
4. What would you add to flux to clean it?
5. How would you skim the borax slag from a lot of melted gold in a pot?
6. If the borax slag is too thin what is added to thicken it?
7. If so thick as to lose gold by skimming what would you do to thin it?
8. What are the indications of impurities in the [illegible]
9. What might it be?
10. What would you add to purify it, and how would you treat it?
11. How would you treat a pot of melted gold and silver to thoroughly mix it?
12. How should small lots be treated?

13. How should the mold for casting the metal be treated?

14. What is requisite for casting a smooth bar?

15. What would you use to cover the bar to prevent oxidization?

16. What is the next step in treating the bar?

17. How is the bar chipped after weighing?

18. How is the chip treated if malleable? If not malleable?

19. What should be done with the remaining chips?

20. If the parallel assays do not agree and the "control" proves false, what is to be done?

21. How should the bar be stamped?

22. When is it called a silver bar? A gold bar?

23. What does the assay value of the bar show?

24. How would you make a large cupel, and how would you refine a few ounces of metal in it?

CHAPTER VIII.

ASSAYING BULLION.

1. The object in assaying bullion is to find out how many parts of it in one thousand consist of pure gold or silver; in other words how many thousandths of it are gold and how many are silver.

2. In writing or stamping the bar we use the decimal marks thus: gold .600 fine, silver .390 fine. Thousandths are always implied and are often called points. Add two points for cupellation loss.

3. All gold bars are assayed with a delicate balance, and generally a half-gramme is taken for the assay, and the pure metal weighed in half-milligrammes.

4. The weights are so arranged that a half-gramme represents the thousand and the half-milligramme a "point" or a thousandth part of the half-gramme.

5. In assaying a silver bar with a cheap balance one gramme may be used. Gold is never found in its pure state, but always alloyed with silver, and sometimes with copper; the bars are sometimes found to have a small amount of platinum which occurs in groins with the gold dust.

6. In parting the silver from the gold the platinum is indicated by turning the nitric acid yellow or straw-color.

7. It is indispensable when the silver is parted from the gold that there should be at least two parts of the silver to one of the gold. If more than three parts are used the gold would crumble to fine powder and be liable to cause a loss. Therefore we always aim to have the alloy two and one-half parts of silver to one of the gold.

8. A good practical assayer can usually judge from the color and appearance of the sample, or from former experience, about how much silver to add to obtain the right proportion in the alloy. An inexeprienced person would find it better to make a preliminary assay with the addition of

enough silver to assure the success of parting, even though the gold may crumble to powder, then dry and weigh it, thereby determining the exact amount of silver to add to the assay proper.

9. Preliminary Assay of a Gold Bar. Take one thousand of the sample and three and a half or four thousand of test silver and wrap it up in three or four thousand of sheet lead. Cupel under a strong heat. The bead is then cleaned, beaten by a hammer on an anvil to a flat plate, annealed to redness once or twice, parted, cupped, dried to a red heat and weighed. A mattress is used in parting on account of the large quantity of the metal. The approximate is the fineness to which the two and one-half parts of silver is to be added to the assay proper. From this the quantity of silver already alloyed with the gold must be deducted.

10. In case of very small bars this kind of assay will do if the gold be twice boiled in nitric acid and cupped with care to prevent loss, then deducting two points for surcharge from the results found.

11. It is not necessary to take 1,000 parts to make the assay just referred to; any amount will do from 100 to 1,000. Suppose we take .236 points and after assaying as above we get 233.2 points of fine gold we have only to add ciphers to the latter number and divide by the former to three places in the quotient which gives us .988 as the fineness.

12. Where there is routine work in bullion assaying it is always best to follow one regular rule and weight of the thousand.

13. If the gold obtained from the 1,000 of the sample weighs 924 the lost weight is that of the silver, except perhaps a few points of base metal, which need not be noticed in this class of assays.

14. The bullion then contains 924 of gold and 76 of silver in 1,000. Multiplying 924 by 2.5 we have 2.310 of sil-

ver required for the parting, of which quantity the bullion contains 76, leaving 2.234 to be added to make two and one-half parts of silver to one of gold.

15. Assay Proper of Gold Bar. Weigh off one thousand chipped from the bar, or if the bar is a large one containing over $500, weigh out one thousand in duplicate chipped from diagonally opposite corners; add the two and one-half parts of pure test silver and about 3 to 4 points of copper. Envelope it in a small cone made of about three thousand of sheet lead, and roll up into a cornet. The lead for this purpose is usually kept on hand, ready made, and cut into about one and one-half inch squares. The weighed assay is transferred directly from the scale pan to the cornet by means of the pincettes.

I weigh my test silver on a small open balance, sitting by the side of it, and having it always loaded with 1,800 of the half-gramme system. This weight stands for a gold alloy of 800 fineness, the other 200 being silver added to the 1,800, making a total of 2,000, or 2.5 times 800. The cornet is then placed on the tray with its respective number.

16. The muffels are heated to a light redness and the assays are placed in them according to their regular order and number. The muffel door is then closed until the assays are uncovered, when it is opened. If by any means the front cupels are not hot enough some hot coals may be placed in the front part of the muffel.

17. A high heat should be kept up during the cupeling and especially at the close when the brightening takes place, because gold is less volatile than silver.

If a silver assay is left in the muffel at a high heat after the lead has passed off it is liable to volatilize and all be found in the roof of the muffle.

18. A gold assay will stand a much higher heat and may be left in the muffel until all are uncovered and then cooled without much precaution, as they are not so apt to sprout.

19. Copper is added to render the metal tougher and more malleable in lamination. No assay should be submitted to the muffel unless the heat is sure to be maintained to finish the work. For want of heat the assay may freeze or solidify, thus rendering it wholly unreliable.

20. The cupel bead is cleaned with a good toothbrush, flattened on an anvil and annealed by heating to a dull redness in the muffel, and then passed through the rollers until it is about two and one-half inches long. If it is hard and cracks on the edges anneal it again. At last, when finished, anneal again and roll it up into an open coil—this is called the cornet as well as the lead capsule—it is then placed in a three ounce mattress and gently boiled in one and one-half ounces of nitric acid, 26 Baume, for ten minutes. The acid is then poured off and replaced by a fresh quantity of acid of 32 Baume, adding a charred lentil, or a bit of charcoal will do, to keep it from bumping; boil for fifteen or twenty minutes. The acid is now poured off and the charcoal must go with it.

21. The gold is washed in three waters, cupped and heated to redness in the muffel, cooled and weighed, and should be in one piece. The weighing of the gold should be less from a half to one point as a surcharge, owing to small traces of silver remaining with the cornet.

22. The result of two assays as described above should agree within a quarter of a point in weight.

EXERCISE.

1. What is the object in assaying bullion?

2. What expression would you use in writing or stamping a bar of bullion?

3. What weights would you use in weighing the cornet?

4. When the half-gramme is used for 1,000 what does the milligramme represent?

5. What may be used in assaying a silver bar?

6. What is indicated when the acid turns straw-color in parting the silver from the gold?

7. How much pure silver is required to make a successful parting from the gold?

8. How would you determine the amount of silver to be added in parting?

9. How would you make a preliminary assay?

10. In what kind of bars would an assay of this description answer?

11. Having taken 236 points and obtained 233.3 of fine gold, how would you determine the fineness?

12. What is the best method to adopt in routine work?

13. If the gold obtained from 1,000 of the sample weighs 924, how much silver would you add to make two and one-half parts?

14. Explain how you would arrive at the amount, including the silver already in the bar?

15. What sized bars require duplicate assays, and how are the chips taken?

16. How is the cupel prepared for placing the cornet into it?

17. When is the most heat required? Why is a gold assay button less volatile than a silver one?

18. Why are they less subject to sprouting?

19. Why is copper added to the assay?

20. How is the button treated after cupelling? What strength of acid is used for boiling it?

21. After parting, how is the gold treated before weighing?

22. What is to be done when two assays from the same bar do not agree?

CHAPTER IX.

ASSAYING OF DOREE BARS, BASE BARS, SILVER BARS, SILVER LEAD, ETC.

1. All of these assays are generally conducted in a similar manner to that of a gold bar. But a preliminary assay is generally required.

2. The Doree bar may need the addition of either gold or silver to produce a suitable alloy for parting. The gold should be absolutely pure, weighed and added to the weighed assay, and cupelled with the proper amount of lead.

3. The difference between the weight of the bead and that of the assay less the gold added represents the base metal.

4. The bead is flattened and parted like all other assays, and the weight of the cornet less that of the gold added with the proper amount of surcharge is the fineness of the gold; it is not always necessary to add gold: this is left to the judgement and experience of the assayer alone.

5. When the bar is about half gold then it becomes necessary to add silver in place of the gold. If a preliminary assay has been made and an approximate of gold and silver determined, then the silver may be added at once and cupelled and the silver determined by difference.

6. In assaying of base bullion the assay sample is cupelled in duplicates. In case of impure bullion each sample should be scorified with a little borax before cupelling.

7. If the lead is very impure and contains a good deal of copper a little test lead will help the scorification. Some assayers prefer to scorify all samples before cupellation, contending that the loss of silver in scorification is less than the loss in cupellation.

9. When a large amount of copper is present in a bar a larger amount of lead should be used.

9. Mitchell has given in the following table an idea of the proportion of lead required to separate copper from gold by cupellation, which is very convenient to refer to, especially when there is a lot of old jewelry to be melted and assayed:

Gold in alloy.	Lead required.
.900	10 parts.
.800	16 parts.
.700	22 parts.
.600	24 parts.
.500	26 parts.
.400 to .050	34 parts.

10. The above is supposed to be an alloy of gold and copper alone, but if half the copper were replaced with silver then only half the above amount of lead would be required to cupel it.

11. In assaying a silver bar, which generally contains more or less copper, by cupellation, it is a good plan, after chipping and weighing your cornet, to also weigh out an equal amount of pure silver and cupel it with an equal amount of pure lead as that used with the cornet; cupel together in the same muffle and with the same heat as a check. The loss of pure silver by cupelling should be added to the assay proper as a loss by cupellation.

12. I have known as high as 25 points to be lost by unskillful cupellation, which should never be more than from five to ten with careful work.

13. Lead, copper, antimony, tin, bismuth, mercury, etc., are always calculated by per cent.

14. Gold, silver, platinum, etc., are always calculated by the ounce troy.

15. To find the value of a bar, multiply the troy ounces by the gold fineness (stated in thousandths) which gives the

weight of pure gold contained, the value of which is computed at $20.67 an ounce.

16. The weight of the bar multiplied by the silver fineness (stated in thousandths) gives the weight of pure silver contained. Silver is reckoned at $1.2929 per ounce.

17. The above value of pure silver and gold multiplied by the fineness of the bar in each metal (stated in thousandths) gives the value per ounce of such bullion for each metal, and the weight of the bar multiplied by the respective value per ounce, gives the value of the entire bar for each. It is well to make the calculation in both ways in order that the one may check the other.

18. Again, the value of pounds and ounces avoirdupois may be computed by the aid of the following table, after multiplying the weight of the bar by the fineness in gold and silver respectively for the contained weights of the pure metals:

	Gold value.	Silver value.
One pound	$301.46	$18.85
One ounce	18.84	1.17
One-quarter ounce	4.76	0.29
One-eighth ounce	2.38	0.14½
One-sixteenth of an ounce	1.19	0.7½

EXERCISE.

1. Why is a preliminary assay more often required in a Doree or base bar than any other?

2. Why is the addition of gold required?

3. How would you determine the base metals in the assay?

4. Is it always necessary to add gold?

5. When the bar is about half gold and half silver what would you add?

6. Would you make base bullion assays in duplicate? Why are they scorified?

7. In case the bead is very impure and contains much copper what would you do?

8. If there is a large amount of copper present in the bar how would you treat it in assaying?

9. What are Mitchell's tables for cupelling gold or alloy?

10. When the alloy is half silver what proportion of lead is added?

11. In assaying a silver bar by cupellation, how is it checked?

12. How much loss of silver will take place with careless work?

13. What metals are calculated and reported in percentages?

14. What metals are calculated by their ounce value?

15. How would you find the value of a gold bar in troy ounces?

16. How is the value of a silver bar found in troy ounces?

17. Why is it necessary to calculate both?

18. How would you make the calculation in avoirdupois pounds and ounces?

CHAPTER X.

HUMID ASSAY OF SILVER BULLION.

This is the Gay Lussac method of determining the fineness of silver bullion, and beyond doubt is the most accurate method of assaying silver yet devised. It has been adopted in all the United States mints and assay offices, and in all the first-class private establishments in the United States.

1. The principle depends upon the fact that silver in nitric acid solution is completely precipitated in the form of chloride by a solution of common salt.

Suppose, for instance, that we wish to know the quantity of pure silver contained in a shilling. The coin is first dissolved in nitric acid, by which means a bluish solution containing silver, copper, and probably other metals, is obtained. It is a known fact that chlorine combines with silver in the presence of other metals to form silver chloride, which is insoluble in nitric acid.

2. The proportion in which the combination takes place is 35.37 of chlorine to every 107.66 of silver; consequently, if a standard solution of pure sodic chloride is prepared by dissolving in water such a weight of salt as will be equivalent to 35.37 grains of chlorine (58.37 grains Na. Cl.) and diluting to the measure of 1,000 grains, every single grain measure of this solution will combine with 0.10766 grains of pure silver to form silver chloride, which is precipitated to the bottom of the vessel in which the mixture is made.

3. In the process of adding the salt solution to the silver, drop by drop, a point is at last reached when the precipitate ceases to form. Here the process must stop, because we have arrived at a point where there is neither salt nor silver in the solution. On looking carefully at the graduated vessel (burette) from which the standard solution has been used, the operator sees at once the number of

grain measures which has been necessary to produce the complete decomposition.

4. For example, suppose the quantity used was 520, grain measure, all that is necessary to be done is to multiply 520 by the coefficient for each grain measure, viz: 0.1076, which shows the amount of pure silver present to be 55.95 grains. It must be understood that there are certain necessary precautions in conducting the above process which I will endeavor to point out.

5. These salt solutions can be made up of pure salt, but it is more troublesome to prepare pure salt and to measure pure water with perfect accuracy than to make a solution which approaches the required standard, and then to rectify it by an addition of salt or water as indicated by the result of an assay of pure silver of known fineness made with it.

6. The easiest way in which to prepare the salt solution is first to make a saturated solution as hereinafter directed, and from this is made the normal solution of which 100 c.c. will exactly precipitate 1,000 of pure silver, as afterwards described; and from the normal salt solution is made the decime salt solution, which is one-tenth as strong as the normal; consequently, 1 c.c. of it precipitates one point of silver.

7. A decime silver solution is also prepared of which 1 c.c. contains one point of silver; consequently the two decime solutions are equivalent, volume for volume, each neutralizing the other.

8. For the preparation of the saturated solution take about a pound of good table salt and dissolve it in about two quarts of water. Put the solution through a course filter, and boil it down to a quarter of the original quantity, causing the greater part of the salt to be deposited. Pour off the liquid and wash the salt quickly before dissolving it.

Redissolve the salt in as little water as possible, and again evaporate until a little of the salt is again deposited. Cool the liquid and put it into a bottle. This is the saturated solution, and contains about 26.5 per cent of its weight of salt.

9. To prepare the normal solution. For the gramme system take 2.08 volumes of the saturated solution and add 97.92 volumes of pure water in any quantity required. For the grain system take 1.33 volumes of the saturated solution and 98.66 volumes of water for any quantity required.

10. If more convenient, take for the gramme system five parts, by any kind of weight, of saturated solution, and 189 parts by weight of water, or one to 37.88.

11. For the grain system, one part, by any kind of weight, of the saturated solution to 58.89 of water.

12. To prepare the decime salt solution, use any volume of the normal solution diluted with 9 such volumes of water. Measure with the large pipette 100 c.c. of water, which pour into the appropriate bottle; remove 10 c.c. of the water by means of the small pipette, and replace it by an equal volume of the normal solution. Mix, by shaking; this small quantity is for correcting the standard of the normal; after this has been done a new decime solution must be prepared if the error of the normal was considerable, and a larger quantity will be required.

To prepare it, measure one litre (1,000 c.c.) of water, or weigh 1,000 grammes at 60 degrees Fahr.; remove 100 c.c. of the water and replace it by 100 c.c. of the corrected normal solution by means of the large pipette.

13. Standardizing the Normal Solution. A thousand of pure silver is dissolved in about 10 c.c. of nitric acid, about 30 Baume, in a bottle of clear glass which will contain about 200 c.c. To facilitate the action the bottle is placed in a vessel containing warm water.

When the silver is dissolved the red fumes are blown out of the bottle by means of a bent glass tube. As soon as the assay has cooled, 100 c.c. of the normal solution are added by means of the pipette and the bottle wrapped with a dark cloth to keep the light from the silver chloride as much as possible, and the stopper, previously dipped in pure water, put in.

The bottle is then briskly shaken for a few minutes, which causes the precipitate to curdle and settle rapidly, leaving the liquid perfectly clear. When the liquid has cleared, the stopper is removed and laid in a clean place so that the moistened part will touch nothing. A c.c. of the decime salt solution is then poured into the bottle. If immediately afterwards a cloudiness appears in the liquid it is evident that the normal solution is weak, because 100 c.c. of it has not precipitated 1,000 of silver. The liquid must be again cleared by shaking and another c.c. of the decime salt solution added, and so on, until no further cloudiness is produced.

A record must be kept of each c.c. used of the decime solution, but the last one is not counted because it gave no cloud, and the one before the last was probably not all required, so it is counted as half. Supposing that 7 c.c. caused precipitation, but the eighth did not, only $6\frac{1}{2}$ must be counted.

14. It now appears as though $1{,}006\frac{1}{2}$ points of silver had been present in the solution, but it is known that there were 1,000, because that quantity was weighed; the normal solution is, therefore, $6\frac{1}{2}$ points weak, and requires a corresponding addition of salt. The quantity of salt required is found by the following:

Rule. Multiply the weight or measure of salt or saturated solution used in making the entire quantity of normal solution by the number of c.c. of decime salt solution

which were necessary to complete precipitation, and divide by 1,000. The result is the weight or measure of the required addition.

As a portion of the normal has been withdrawn for the test for making the decime solution, the quantity thus found may be corrected by the deduction of a corresponding percentage; but it is not worth while, unless either many tests have been made, or but a small quantity of normal has been prepared, for even though the addition of salt required may be considerable, it is evident, from the fact that the normal is weak, that the saturated solution used was less strong, or the salt less pure, than was supposed, so that the added quantity will have the same deficiency in proportion. If dry salt was used in making the normal, and consequently will be used also in the correction, the required quantity should be dissolved in some of the original normal poured into a beaker for that purpose, and then mixed with the main stock, the beaker being rinsed with a very little water and tnat also added. Another test must then be made, and, if necessary, another correction.

If the first addition of 1 c.c. of decime salt solution produces no precipitate, it is known that the normal is either correct or too strong; to ascertain which, add 2 c.c. of decime silver solution. One of these is consumed in neutralizing the c.c. of decime salt previously added; hence only one is counted. Shake down and add another c.c. of decime silver; if this produces no cloud, the normal is correct within at most a point, and may be accepted, for it is needless to make it perfect, for reasons which will appear hereafter. If a cloud is produced, shake down again, and continue adding decime silver solution and shaking down until the last added c.c. causes no cloudiness; then, as with the salt, reject the last c.c. and half of the preceding one. Sup-

posing that, in all, 5 c.c. have been used, we reject one of the first two added, because it only counteracted the c.c. of decime salt previously added; we also reject the last, because it gave no precipitate, and the one before the last we count as a half c.c. Thus we have $2\frac{1}{2}$ c.c. of decime silver solution which were necessary to complete the decomposition of the salt in 100 c.c of the normal. Apparently only $997\frac{1}{2}$ points of silver were dissolved, but we know that 1,000 were so; consequently the normal is $2\frac{1}{2}$ points too strong, and water must be added. The quantity of water is found by the following:

15. "Rule. Multiply the quantity, by weight or measure, of water used in making the entire quantity of normal solution by the number of c.c. of decime silver solution which were necessary to complete the assay, and divide by 1,000. The result is the quantity of water to be added to the normal solution. Mix thoroughly.

A correction for the percentage of the normal which has been used is more necessary in this case; still it is hardly worth the trouble, because, if the error of the normal is large, a second rectification will probably be required, and if it is small, the difference will not be perceived. After mixing, test again; when the normal is sufficiently exact, make a new decime salt solution.

16. Examples. The normal solution was made with 5 pounds avoirdupois of saturated solution, and a test assay on pure silver required $8\frac{1}{2}$ c.c. of decime salt solution to finish; then 5 times $8\frac{1}{2}$ makes 42.5, and this divided by 1,000 gives 0.0425 pounds of saturated solution to be added to the normal. A pound avoirdupois is equal to 7,000 grains Troy, and, multiplying this by 0.0425, we have 297.5 grains.

Again the normal solution was made with $189\frac{1}{2}$ pounds of water, and proves to be too strong, a test assay requiring $5\frac{1}{2}$ c.c. of decime silver solution to finish; then, 189.5 multiplied by 5.5 gives 1,042.25, which, divided by 1,000, gives 1.04 pounds of water to be added."

If dry salt has been used, or if the saturated solution or

the water had been measured by volume, the same kind of calculation would give the required result in terms of the weight or measure used.

When the normal solution is within about a point of being correct, it may be accepted, perfect accuracy being needless on account of the changes of volume produced by alterations of the temperature, for which a correction must be made as hereafter directed, and includes any inaccuracy in the standardizing; for the present, however, the solution will be supposed to be exact.

17. The Assay.—For the sake of convenience, a c.c. of either of the decime solutions will be called a point of silver or a point of salt, as the case may be; also 100 c.c. of the normal solution will be called a thousand of salt.

One thousand of salt requires 1,000 of silver, and such a weight of the bullion is taken for the assay as contains, as nearly as may be, 1,000 of silver. This being dissolved and 1,000 of salt added, we then proceed, by means of the decime solutions, to ascertain how many points of silver more or less than 1,000 the assay contains. Knowing the weight taken, and having found the weight of the contained silver, it is easy to find by proportion what weight of silver 1,000 of the bullion contains, which is its fineness.

In order to be able to take the required weight of the sample we must have an approximate knowledge of its silver fineness; this is obtained by means of a preliminary assay by cupellation, and, if necessary, parting. As we know from experience that there is a certain loss of silver in the cupellation, we add to the result of the preliminary assay such a number of points as the judgment may dictate. From the approximate fineness thus obtained we calculate the weight which must be taken in order that the assay may contain nearly 1,000 of silver: Thus, suppose the cupellation (and parting) gave a silver fineness of .864, and we add

3 points for loss, making .867, then, as 867 are to 1,000 so are 1,000 to 1,153.4, and we weigh off 1,154; hence the

Rule.—Divide 1,000,000 by the number of points of approximate fineness; the result is the desired weight in points.

Dissolve the quantity of the sample in about 7 c.c. of nitric acid, in the manner directed for the standardizing of the normal solution; cool, add 1,000 of salt, shake down and add a point of salt. If a cloud is produced, proceed to complete the assay with salt, as in testing the normal solution, keeping a record of the number of points added, finally rejecting the last and half of the preceding one. Suppose 1,154 of the bullion to have been taken, and that three points of salt have given a precipitate, the fourth none, we have then found that 1,154 points of the bullion contain 1,002½ points of silver; to find the fineness, we take the proportion, as 1,154 are to 1,002.5 so are 1,000 to 869.7; as not less than a point is usually stamped on a bar, we may say the bullion is .869 fine.

If the first added point of salt gives no precipitate, add a point of silver to neutralize it, shake down and add another; if this produces no precipitate, the assumed fineness was correct; if otherwise, proceed to finish with silver in the same manner as with salt; then rejecting the first point because it was required to counteract the point of salt, and the last because it gave no result, also half of the preceding one because it was probably only required in part, deduct the remainder of the added points from 1,000, which leaves the number of points in the assay. If, as before, 1.154 of the bullion were taken, and one added point of salt gave no precipitate, and four successive points of silver gave a precipitate, the fifth none, then it is known that 1,154 of the bullion contain 998½ of silver, and as 1,154 are to 998.5 so are 1,000 to 865.25, or the bullion is .865 fine. Hence to find the fineness, the following:

18. Rule.—Multiply the points of silver found by 1,000, and divide by the points of bullion taken.

Greater exactitude can be attained by finishing with half points, but for ordinary purposes it is not necessary. The gold fineness is found in the preliminary assay by cupellation and parting.

It is better to finish with salt than with silver, so the weight of bullion taken for the assay should be such as to contain a little more, rather than less than 1,000 of silver; and if it is not so, and is found to contain less, a number of points of silver may be added at once, so as to make more than 1,000; the assay is then finished with salt. An account must be kept of the silver and salt added, the one —, the other —. If more than eight points of salt or silver are required to finish, it is advisable to make another assay on the basis of the result found.

The last trace of precipitate is somewhat difficult to discern. It can be seen best by looking obliquely upward through the liquid, while holding the bottle toward the light. Another help is to have a black background, for which a black felt hat answers. The writer and some others have found it advantageous to have the assay solution tinged by copper; the white silver chloride shows very plainly in the blue solution. An experienced assayer, on observing that the first added point of salt causes a considerable precipitate immediately, will add several more points before shaking down, being able to judge about how many will be required; he can also tell, almost with certainty, when another point will be without effect.

In case the furnace is not fired, a preliminary assay may be made by means of the blowpipe. It is not necessary that any special weight be taken, therefore select a piece of bullion which may weigh about 100, more or less; weigh it, cupel it with lead before the blowpipe flame, not allowing

the flame to touch the metal, but heating the cupel around it by directing the point first on one side and then on another, weigh the bead, part and weigh the gold if there is much; then as the weight of the silver is to that of the assay, so is 1,000 to the weight of the bullion to be taken for the volumetric assay, to which a few points may be added for the loss, which is likely to be greater, at least in inexperienced hands, than in the muffle. The gold may be calculated for 1,000 on the same principle, but it may be better to dissolve 1,000 of the bullion in nitric acid and weigh the gold from that, the only difficulty being that it is likely to be in finer powder than when parted from a bead which has been purified from base metal by cupellation.

An excellent preliminary, and even an accurate assay, may be made by means of a Mohr burette. Dissolve 1,000 of the bullion in the usual manner. Charge the burette very accurately with normal solution, and run that into the assay bottle, first in larger, then in smaller quantities, finally drop by drop, shaking down each time, until the last drop or two produces no precipitate. The value of a drop may be ascertained by noting how many drops lower the float 1 c.c. The last addition, which produces no precipitate, is not counted, and the preceding is counted for half its value. The burette should be read after each addition toward the end; it should be of 100 c.c. capacity, graduated to tenths, and furnished with a float. If, by accident, an excess of salt solution is run in, add ten or more points of decime silver solution, making a note of it; and then finish with salt. If preferred, the assay may be finished with decime salt solution from a second burette, or from the small pipette, but with care this will not be necessary, as the normal can be measured to less than a point. The number of c.c. necessary for complete precipitation, multiplied by ten, is the fineness, provided no addition of decime silver has been made; otherwise that must be deducted. Special care must

be taken that no air remains in the jet of the burette when charged, to which end it is best to partly charge it from below, by suction, and then to fix it in the stand and fill it from above.

Correcting the Assay.—It has thus far been supposed that the normal solution was accurately standardized, so that 100 c.c. would exactly precipitate 1,000 of silver. In order that this may be the case, it must not only have been made of correct strength, but it must always be used at the same temperature, which cannot well be. For this reason a check assay is made, on pure silver, which each set of bullion assays, a number of which can be conducted at the same time, and are corrected according to the error found, whether that is caused by expansion or contraction of the solutions, owing to a change of the temperature, or from inaccurate standardizing.

The result of an assay of pure silver should be 1,000 fine; if it gives more or less, the assay of each sample of bullion must be corrected in proportion to its fineness. This is arrived at with sufficient exactness by adding to, or subtracting from, the number of points found in the assay, the amount of the error of the check, before calculating the fineness of the bullion. Thus: If the result of the check is $2\frac{1}{2}$ points above 1,000, that quantity must be deducted; if below, added. Suppose the check was $2\frac{1}{2}$ points high, and 1,154 of bullion gave $1,005\frac{1}{2}$; we deduct $2\frac{1}{2}$ from that, leaving 1,003, from which we then calculate the fineness, which is 870. If the check had been $1\frac{1}{2}$ low, we should have added $1\frac{1}{2}$, making 1,007 in 1,154, and the fineness would have been .873.

"Suppose the alloy has a standard of about 900 thousandths, we have the following proportion:

900 thousandths: 1,000 of alloy:: 1,000 thausands: x= 1111.1.

If that weight be now taken to ascertain the standard of the alloy, it may be found, for instance, that to the measure of one-thousandth of salt it is yet necessary to add 4 thousandths of salt to precipitate the whole of the silver; that is to say, that 1111.1 of alloy really contain 1,004 of silver. From this result the real standard of the alloy may be found to be 903.6, by the following equation:

1111.1: 1004:: 1000:×=903.6. But such calculations, however simple, should be avoided where numerous daily assays are made, not only on account of the time consumed, but still more from the errors to which such operations are necessarily exposed. Fortunately, all these inconveniences may be avoided by the use of tables, which entirely free the assayer from calculation.

"Wishing in weighing the alloy to avoid fractions of thousands, and only making use of tenths and half-tenths of thousands, the weight of alloy increases, starting from a gramme, from 5 to 5 thousands, and the corresponding standard for each of these weights has been sought, all containing one gramme of pure silver. Thus the weight 1,020 of alloy, in which there are 1,000 of silver and 20 of copper, corresponds to the standard 980.39, obtained by the proportion—1020: 1000:: 1000:×=980.39.

"On this principle are formed the first and second columns of the table marked Salt. The first contains the weight of each alloy, and the second its corresponding standard. The following columns, 1, 2, 3, etc., milligrammes of copper less.

"Another table, constructed in the same manner as the preceding, and marked nitrate of silver, gives the standard of the alloy when, under the weight given in the first column, it contains 1, 2, 3, etc., milligrammes less silver, and as much more copper. Thus, for example, an alloy of the weight of 1,020 (1,000 silver and 20 copper) has for its standard 98[illegible].4 in both tables. If it always contains in the

same weight 4 more silver and consequently 4 less copper, its standard would be 984.3, and would be found in the 'Salt' table at the intersection of the column 4, and the horizontal line 1020. If, on the contrary, it contains 4 less of silver and 4 more of copper, its standard will be 976.5, and will be found in the 'Nitrate of Silver' table, at the intersection of the column 4, and the horizonal line 1020."

TABLE A.—FOR DECIMAL SALT SOLUTION.

Tables for Determining the Standard of any Silver Alloy by Employing an Amount of Alloy, Always Approximately Containing the Same Amount of Silver.

COMMON SALT.

Weight of Alloy Assayed, in Milligramme.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
	Cubic centimeters of decinormal salt solution added correspond to a content of fine silver of—										
1000.....	1000.0										
1005.....	995.0	996.0	997.0	998.0	999.0	1000.0					
1010.....	990.1	991.1	992.1	993.1	994.1	995.0	996.0	997.0	998.0	999.0	1000.0
1015.....	985.2	986.2	987.2	988.2	989.2	990.1	991.1	992.1	993.1	994.1	995.1
1020.....	980.4	981.4	982.4	983.3	984.3	985.3	986.3	987.2	988.2	989.2	990.2
1025.....	975.6	976.6	977.6	978.5	979.5	980.5	981.5	982.4	983.4	984.4	985.4
1030.....	970.9	971.8	972.8	973.8	974.8	975.7	976.7	977.7	978.6	979.6	980.6
1035.....	966.2	967.1	968.1	969.1	970.0	971.0	972.0	972.9	973.9	974.9	975.8
1040.....	961.5	962.5	963.5	964.4	965.4	966.3	967.3	968.3	969.2	970.2	971.1
1045.....	956.9	957.9	958.8	959.8	960.8	961.7	962.7	963.6	964.6	965.5	966.5
1050.....	952.4	953.3	954.3	955.2	956.2	957.1	958.1	959.0	960.0	960.9	961.9
1055.....	947.9	948.8	949.8	950.7	951.7	952.6	953.5	954.5	955.4	956.4	957.3
1060.....	943.4	944.3	945.3	946.2	947.2	948.1	949.1	950.0	950.9	951.9	952.8
1065.....	939.0	939.9	940.8	941.8	942.7	943.7	944.6	945.5	946.5	947.4	948.4
1070.....	934.6	935.5	936.4	937.4	938.3	939.3	940.2	941.1	942.1	943.0	943.9
1875.....	930.2	931.2	932.1	933.0	933.9	934.9	935.8	936.7	937.7	938.6	939.5
1080.....	925.9	926.8	927.8	928.7	929.6	930.6	931.5	932.4	933.3	934.3	935.2
1085.....	921.7	922.6	923.5	924.4	925.3	926.3	927.2	928.1	929.0	930.0	930.9
1090.....	917.4	918.3	919.3	920.2	921.1	922.0	922.9	923.8	924.8	925.7	926.6
1095.....	913.2	914.2	915.1	916.0	917.0	917.8	918.7	919.6	920.5	921.5	922.4
1100.....	909.1	910.0	910.9	911.8	912.7	913.6	914.5	915.4	916.4	917.3	918.2
1105.....	905.0	905.9	906.8	907.7	908.6	909.5	910.4	911.3	912.2	913.1	914.0
1110.....	900.9	901.8	902.7	903.6	904.5	905.4	906.3	907.2	908.1	909.0	909.9
1115.....	896.9	897.8	898.6	899.5	900.4	901.3	902.2	903.1	904.0	904.9	905.8
1120.....	892.9	893.7	894.6	895.5	896.4	897.3	898.2	899.1	900.0	900.9	901.8
1125.....	888.9	889.8	890.7	891.6	892.4	893.3	894.2	895.1	896.0	896.9	897.8
1130.....	885.0	885.8	886.7	887.6	888.5	889.4	890.3	891.1	892.0	892.9	893.8
1135.....	881.1	881.9	882.8	883.7	884.6	885.5	886.3	887.2	888.1	889.0	889.9
1140.....	877.2	878.1	878.9	879.8	880.7	881.6	882.5	883.3	884.2	885.1	886.0
1145.....	873.4	874.2	875.1	876.0	876.9	877.7	878.6	879.5	880.3	881.2	882.1
1150.....	869.6	870.4	871.3	872.2	873.0	873.9	874.8	875.7	876.5	877.4	878.3
1155.....	865.8	866.7	867.5	868.4	869.3	870.1	871.0	871.9	872.7	873.6	874.5
1160.....	862.1	862.9	863.8	864.7	865.5	866.4	867.2	868.1	869.0	869.8	870.7
1165.....	858.4	859.2	860.1	860.9	861.8	862.7	863.5	864.4	865.2	866.1	866.9
1170.....	854.7	855.6	856.4	857.3	858.1	859.0	859.8	860.7	861.5	862.4	863.2
1175.....	851.1	851.9	852.8	853.6	854.5	855.3	856.2	857.0	857.9	858.7	859.6
1180.....	847.5	848.3	849.2	850.0	850.8	851.7	852.5	853.4	854.2	855.1	855.9
1185.....	843.9	844.7	845.6	846.4	847.3	848.1	848.9	849.8	850.6	851.5	852.3
1190.....	840.3	841.2	842.0	842.9	843.7	844.5	845.4	846.2	847.1	847.9	848.7
1195.....	836.8	837.7	838.5	839.3	840.2	841.0	841.8	842.7	843.5	844.3	845.2
1200.....	833.3	834.2	835.0	835.8	836.7	837.5	838.3	839.2	840.0	840.8	841.7
1205.....	829.9	830.7	831.5	832.4	833.2	834.0	834.8	835.7	836.5	837.3	938.2
1210.....	826.4	827.3	828.1	828.9	829.7	830.6	831.4	832.2	833.1	833.9	834.7
1215.....	823.0	823.9	824.7	825.5	826.3	827.2	828.0	828.8	829.6	830.4	831.3
1220.....	819.7	820.5	821.3	822.1	822.9	823.8	824.6	825.4	826.2	827.0	827.9
1225.....	816.3	817.1	818.0	818.8	819.6	820.4	821.2	822.0	822.9	823.7	824.5
1230.....	813.0	813.8	814.6	815.4	816.3	817.1	817.9	818.7	819.5	820.3	821.1
1235.....	809.7	810.5	811.3	812.1	813.0	813.8	814.6	815.4	816.2	817.0	817.8
1240.....	806.5	807.3	808.1	808.9	809.7	810.5	811.3	812.1	812.9	813.7	814.5
1245.....	803.2	804.0	804.8	805.6	806.4	807.2	808.0	808.8	809.6	810.4	811.2
1250.....	800.0	800.8	801.6	802.4	803.2	804.0	804.8	805.6	806.4	807.2	808.0
1255.....	796.8	797.6	798.4	799.2	800.0	800.8	801.6	802.4	803.2	804.0	804.8

TABLE B.—FOR DECIMAL SILVER SOLUTION.

Tables for Determining the Standard of Any Silver Alloy by Employing an Amount of Alloy, Always Appoximately Containing the Same Amount of Silver.

NITRATE OF SILVER.

Weight of Alloy Assayed, in Milligramme.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
	Cubic centimeters of decinormal silver solution added correspond to a content of fine silver of—										
1000	1000.0	999.0	998.0	997.0	996.0	995.0	994.0	993.0	992.0	991.0	990.0
1005	995.0	994.0	993.0	992.0	991.0	990.0	989.0	988.1	987.1	986.1	985.1
1010	990.1	989.1	988.1	987.1	986.1	985.1	984.2	983.2	982.2	981.2	980.2
1015	985.2	984.2	983.2	982.3	981.3	980.3	979.3	978.3	977.3	976.4	975.4
1020	980.4	979.4	978.4	977.4	976.5	975.5	974.5	973.5	972.5	971.6	970.6
1025	975.6	974.6	973.7	972.7	971.7	970.7	969.8	968.8	967.8	966.8	965.8
1030	970.9	969.9	968.9	968.0	967.0	966.0	965.0	964.1	963.1	962.1	961.2
1035	966.2	965.2	964.2	963.3	962.3	961.3	960.4	959.4	958.4	957.5	956.5
1040	961.5	960.6	959.6	958.6	957.7	956.7	955.8	954.8	953.8	952.9	951.9
1045	956.9	956.0	955.0	954.1	953.1	952.1	951.2	950.2	949.3	948.3	947.4
1050	952.4	951.4	950.5	949.5	948.6	947.6	946.7	945.7	944.8	943.8	942.9
1055	947.9	946.9	946.0	945.0	944.1	943.1	942.2	941.2	940.3	939.3	938.4
1060	943.4	942.4	941.5	940.6	939.6	938.7	937.7	936.8	935.8	934.9	934.0
1065	939.0	938.0	937.1	936.1	935.2	934.3	933.3	932.4	931.4	930.5	929.6
1070	934.6	933.6	932.7	931.8	930.8	929.9	929.0	928.0	927.1	926.2	925.2
1075	930.2	929.3	928.4	927.4	926.5	925.6	924.7	923.7	922.8	921.9	920.9
1080	925.9	925.0	924.1	923.1	922.2	921.3	920.4	919.4	918.5	917.6	916.7
1085	921.7	920.7	919.8	918.9	918.0	917.0	916.1	915.2	914.3	913.4	912.4
1090	917.4	916.5	915.6	914.7	913.8	912.8	911.9	911.0	910.1	909.2	908.3
1095	913.2	912.3	911.4	910.5	909.6	908.7	907.8	906.8	905.9	905.0	904.1
1100	909.1	908.2	907.3	906.4	905.4	904.5	903.6	902.7	901.8	900.9	900.0
1105	905.0	904.1	903.2	902.3	901.4	900.4	899.5	898.6	897.7	896.8	895.9
1110	900.9	900.0	899.1	898.2	897.3	896.4	895.5	894.6	893.7	892.8	891.9
1115	896.9	896.0	895.1	894.2	893.3	892.4	891.5	890.6	889.7	888.8	887.9
1120	892.9	892.0	891.1	890.2	889.3	888.4	887.5	886.6	885.7	884.8	883.9
1125	888.9	888.0	887.1	886.2	885.3	884.4	883.6	882.7	881.8	880.9	880.0
1130	885.0	884.1	883.2	882.3	881.4	880.5	879.6	878.8	877.9	877.0	876.1
1135	881.1	880.2	879.3	878.4	877.5	876.7	875.8	874.9	874.0	873.1	872.3
1140	877.2	876.3	875.4	874.6	873.7	872.8	871.9	871.0	870.2	869.3	868.4
1145	873.4	872.5	871.6	870.7	869.9	869.0	868.1	867.2	866.4	865.5	864.6
1150	869.6	868.7	867.8	867.0	866.1	865.2	864.3	863.5	862.6	861.7	860.9
1155	865.8	864.9	864.1	863.2	862.3	861.5	860.6	859.7	858.9	858.0	857.1
1160	862.1	861.2	860.3	859.5	858.6	857.8	856.9	856.0	855.2	854.3	853.4
1165	858.4	857.5	856.6	855.8	854.9	854.1	853.2	852.4	851.5	850.6	849.8
1170	854.7	853.8	853.0	852.1	851.3	850.4	849.6	848.7	847.9	847.0	846.1
1175	851.1	850.2	849.4	848.5	847.7	846.8	846.0	845.1	844.3	843.4	842.5
1180	847.5	846.6	845.8	844.9	844.1	843.2	842.4	841.5	840.7	839.8	839.0
1185	843.9	843.0	842.2	841.3	840.5	839.7	838.8	838.0	837.1	836.3	835.4
1190	840.3	849.5	838.7	837.8	837.0	836.1	835.3	834.5	833.6	832.8	831.9
1195	836.8	836.0	835.1	834.3	833.5	832.6	831.8	831.0	830.1	829.3	828.4
1200	833.3	832.5	831.7	830.8	830.0	829.2	828.3	827.5	826.7	825.8	825.0
1205	829.9	829.0	828.2	827.4	826.6	825.7	824.9	824.1	823.2	822.4	821.6
1210	826.4	825.6	824.8	824.0	823.1	822.3	821.5	820.7	819.8	819.0	818.2
1215	823.0	822.2	821.4	820.6	819.7	818.9	818.1	817.3	816.5	815.6	814.8
1220	819.7	818.8	818.0	817.2	816.4	815.6	814.7	813.9	813.1	812.3	811.5
1225	816.3	815.5	814.7	813.9	813.1	812.2	811.4	810.6	809.8	809.0	808.2
1230	813.0	812.2	811.4	810.6	809.8	808.9	808.1	807.3	806.5	805.7	804.9
1235	809.7	808.9	808.1	807.3	806.5	805.7	804.9	804.0	803.2	802.4	801.6
1240	806.5	805.6	804.8	804.0	803.2	802.4	801.6	800.8	800.0	799.2	798.4
1245	803.2	802.4	801.6	800.8	800.0	799.2	798.4	797.6	796.8	796.0	795.2
1250	800.0	799.2	798.4	797.6	796.8	796.0	795.2	794.4	793.6	792.8	792.0
1255	796.8	796.0	795.2	794.4	793.6	792.8	792.0	791.2	790.4	789.6	788.8

EXERCISE.

1. What is the principal of the humid assay?

2. What are the combining weights of chlorine and silver, and what is the molecular weight?

3. When a salt solution is dropped into a silver solution until no precipitate forms, what does it indicate?

4. Suppose you had dropped salt solution into a silver solution until no more p.p. takes place, and your burette records 520, how would you caluculate the amount of silver in solution in the parts per thousand?

5. Which is the best way to prepare the salt solution, by weight or measurement?

6. How many salt solutions is it necessary to make, and what are they termed?

7. What other solution is necessary, and what is it termed?

8. How would you prepare a saturated solution of common salt?

9. How would you prepare the normal salt solution? For the gramme system; by measure?

10. How by weight by the gramme system?

11. How by the grain system by weight?

12. How would you prepare the decime salt solution?

13. How would you standardize the normal salt solution with the 1,000 of pure silver?

14. If your normal salt solution is $6\frac{1}{2}$ too weak, what is the rule for correcting it?

15. Suppose we find that the decime silver solution is $2\frac{1}{2}$ c.c. too strong, what is the rule for correcting it?

16. Suppose the normal salt solution was made with 5 pounds avoirdupois of saturated solution, and a test on pure silver required $8\frac{1}{2}$ c.c. of decime salt solution to finish it, what is the rule of correction?

17. What is a c.c. of decime, of salt or silver solution called?

18. What is the rule to find the fineness of a silver bar when the determination is made in points?

CONCLUSION TO PART I.

In the assaying of bullion it is necessary to save the residue of the chips from the bar, wrap them in paper carefully, and mark the number of the bar thereon; should there be any reclamation or error in the assay, you have them to refer to for a re-assay. If the bar proves to be short in the value stamped upon it the assayer must pay the difference, if he wishes his assay to pass in the market; though the error may have been made in the mint, the private assayer has to suffer the loss. On the other hand, if a bar is stamped too low, the purchaser of the bar is the gainer and it is never heard of. An instance is in my knowledge where a reclamation was made from a bar which had been re-melted and assayed in a private office in San Francisco. A short time afterwards the melter of the bar was arrested for embezzlement from the melting pot and substituting half-dollars to make up the weight. No reclamation should be made or allowed, except on a mint certificate, and while their assaying is but little, if any, better than that of some private offices, it is necessary to have a place to submit all errors for correction.

PART II.

INTRODUCTION TO PART II.

Among the many processes of assaying metals and ores there is but little new matter to be added to the various processes now published and practiced. My object, therefore, throughout this work, is not so much to present any new methods, as to abbreviate, compile, copy, and quote some of the best now in use, divesting them of much superfluous matter and rendering them simple and plain to the beginner; also to arrange it in such form that the study and practice can be taken up in systematic order and in sections, so that when the student has passed through the work and has had the practical illustrations, he cannot fail to understand the principles of the work he is conducting.

It is not my intention to here introduce all the different methods for the determination of the various metals in ores, but to give one or two of the most simple and accurate, thus enabling him to understand the main points in the various processes and digest it in his mind, rather than to dig it out of a voluminous chapter of reading matter. It is intended for the beginner and to assist the practical miner and prospector. For those who have a knowledge of algebra and higher mathematics, I would recommend Cook's Philosophy, Fresenius, and Francis Sutten on Volumetric Analysis. But in the present work I feel confident that the student will find many short-cuts to obtain results which have heretofore been considered extremely difficult. I know that it is not nearly so clear and plain as it ought to be and hope at some future time to revise it, with some improvements, but to those interested I would say, examine the book and point out the errors, this being my first attempt to simplify a work of which I have long felt the need, and I hereby submit it to the professors and teachers of the various institutions of learning for their criticism.

PREPARATION OF THE ORE SAMPLE.

Accurate sampling of the ore is essential, for if the sample does not truly represent the lot from which it was taken, the subsequent assay will be valueless.

It is one of the most absurd customs, and one the most frequently practiced, to make the one-stone assay. It cannot be too severely ridiculed, for it would be just as reasonable for a geologist to land on a strange coast and pronounce the whole country similar to what he saw under his feet, or as correct in judgment for a burglar to enter a hardware store during the night and bring the first thing he handled to light and say the whole store was stocked with axes, as to say the one stone was a true sample of the vein of ore.

There are many methods in vogue for sampling the ore from a mine, among which may be mentioned the hand sampling, mechanical sampling, quartering, halving, split, shovel, channeling sampling, etc. It makes very little difference which of these methods are adopted so long as the ore or pulp is thoroughly mixed.

The Taylor rock crusher is a good one for small lots. After the ore has been put through it, it must then be passed through a coarse sieve of forty mesh to the lineal inch; then spread in a layer and divide it with a spatula into quarters: reject two quarters and sweep cleanly off the table. The other two quarters are again mixed and pulverized either in Buck's patent mortar or bucking board. A common iron mortar will do, although it is slower work. The ore must be pulverized finely enough to pass through a sixty-mesh sieve, some advocate a hundred-mesh sieve, but I see no advantage in it, as the pulp when assayed should be thoroughly fused with the fluxes added and converted into a glass.

After passing the pulp through the last sieve, it should be

spread out, heaped, quartered, and sampled as before until the sample is gradually reduced in quantity to a few ounces, which is then spread out upon glazed paper or oil cloth. Lift the edges of the cloth or paper, thus causing the ore to roll upon itself, and finally heap it up, flatten it out with a spatula, and weigh out the charge from different parts of the pulp. It is indispensable that the sample be thoroughly mixed, and if the pulp is damp it must be dried before sampling.

It often happens that samples of pulp come for assay in bottles corked and sealed, as a check upon other assayers or smelting works who are purchasers of the ore. In all such cases it is supposed that the ore has been properly sampled before bottling. In such instances it is proper to first test the sample in order to know what dressing to use for the assay, and to determine the percentage of sulphurets, if it contains any. To do this, weigh out a small amount of the pulp, place upon a watch crystal and pan it out; dry, and determine the percentage of sulphurets and treat the ore accordingly. If the sample is damp, determine the amount of moisture and report it in the percentage.

All such samples should be carefully treated by weighing out three charges and assaying them with the fluxes required. The result is reported from the mean of the three assays, for it matters not how fine you may mix or pulverize the ore, it is almost impossible to get two assays to run exactly alike, especially in gold ores; and since there will be always be a dollar or two a ton difference it is always best to make three or more assays and take the mean of the lot as the true result.

New and clean crucibles must always be used for the work, and all implements used in powdering and sifting must be cleaned lest some former ore may contaminate it. Sometimes a mere wiping out of the mortar with a cloth

will do, but if a rich ore has been used, all must be cleaned by grinding some glass or barren sand before pulverizing the sample. Keep a tag with number and mark of each sample separate in pans and be careful not to get the numbers mixed, or all your work is worthless.

The following notes are imperative. Ores to be assayed by the wet method should be sampled as above stated before being submitted to the solvent action of the re-agent.

1. In filtering large quantities of liquid use a whole sheet of paper, fold it three or four times, and cut straight across at a distance from the corner equal to the distance in diameter of the required filter, then turn it to an arc of a circle, open to the twice folded paper so that it shall form a cone having one thickness on the one side, and three on the other.

2. Small filters can be purchased of various sizes and qualities to fit the funnels in use. When not on hand, cut from the sheet and fit to funnel as above stated. All filters and funnels should be adapted to the bulk of the precipitate.

When a substance is to be weighed on the filter, the filter must be counterposed by another, or its weight known, in order that the net weight of the substance may be obtained.

3. The filter must be dried prior to use, at the temperature at which the substance is afterwards to be dried on it.

4. In filtering, fill the filter often, not waiting for it to drain.

5. In washing the substance on the filter, let it drain before each addition of water.

6. It is generally best to let a precipitate settle before filtering, then filter the liquid first as far as practicable.

7. It is a good plan in filtering silica, lime, etc., after the first decantation to add water to the precipitate; stir it; let settle; sometimes boil, and again settle and filter off several times before bringing the precipitate on the filter.

8. As a general rule in pouring from one vessel to another, hold a glass rod to the lip, and let it run down the rod and against the side of the filter or other receiver.

9. In filtering from the filter to the filtrate, do not allow the liquid to fall splashing into the receiver, but let it trickle down its side; even if the filtrate is not required, it is not clean work.

10. There are several ways of determining when the washing or the precipitate is completed; if the filtrate was acid, the washings must cease to redden blue litmus paper, except when directed to wash with acidulated water.

11. If alkaline, they must not discharge the color of reddened litmus paper. If the water used be pure (as it should be), a drop from the filter, evaporated on a piece of glass or platinum foil will leave no film, or only a slight speck.

12. The filter and its contents may be dried in the funnel. The drying should be continued until two weighings, after thorough cooling in the dessicator, give the same result.

13. In removing the dried precipitate from the filter, open it carefully and invert on a sheet of glazed paper, loosening the p.p. carefully, and scraping it off. Then double it and rub the surfaces together; lay it flat, and brush it with a rather hard brush; heat, cool, and weigh.

14. Fold and burn the filter on a platinum wire in the flame until the filter is completely incinerated, and add the ash to the precipitate.

15. When the precipitate is to be dried and weighed on the filter, two filters of exact weight, one to counterbalance the other, must be arranged. Place one filter accurately within the other, and both in the funnel; when the filtration and washing are completed the filters and precipitate are dried together, and the weighing and the empty filter is put on the weight pan. But for fear some of the substance may

pass through the first filter, it is better to wet and dry the empty filter by itself.

16. In some cases, like chloride of silver or sulphate of lead, it may be precipitated and the water drawn off, dried and weighed in the porcelain crucible, and the weight of the crucible deducted from the total weight gives the weight of the precipitate.

17. In volumetric assays always use the Mohr burette, fitted in suitable stands with clamps. In all accurate work, use the float as an indicator.

18. When beakers are used for boiling, a sand bath must be used, and in using the glass rod, never drop it in the beaker. You will surely crack it if you do. But very gently reach the bottom of the beaker and let it rest against the side.

19. Never put cold water into a hot dish, but always heat and cool gradually.

20. Wash all glassware and dishes after using. Vessels used which have contained chlorine should be washed several times in warm water; a wet ball of paper is a good thing to clean wide-mouthed bottles. No work is complete until every article has been washed and cleaned.

EXERCISES.

1. How are large quantities of liquid filtered?
2. How is the net weight of a substance weighed on a filter obtained?
3. At what temperature is the filter dried?
4. What is said of filling the filter?
5. How is a substance washed on the filter?
6. Should a precipitate settle before filtering?
7. How are silica, lime, etc., filtered?
8. What is the general rule in pouring from one vessel to another?

9. What is the method of filtering from the filter to the filtrate?

10. How do you determine when the washing of the precipitate is completed?

11. Should any film be left when a drop from the filter is evaporated on a piece of glass?

12. How long is the drying process continued?

13. How is the dried precipitate removed from the filter?

14. What is added to the precipitate?

15. How do you prepare for drying and weighing the precipitate on the filter?

16. How do you proceed in cases like chloride of silver or sulphate of lead?

17. What burette is used in volumetric assays?

18. How is the glass rod used?

19. What is said of heating and cooling?

20. What is said in regard to the care of all glassware and dishes?

WEIGHING THE CHARGE.

1. The pulp scales should have pans with handles attached so that they can be taken from the scales and emptied into the mixing mortar.

Put the weights on the left hand pan and weigh the pulp accurately. After a little practice it will not be necessary to weigh the fluxes, except in some cases of nitre or flour.

2. I prefer the measuring of the principal fluxes in all cases. I have a tin measure with handle like a spoon which holds one and one-half ounces of bi-carbonate of soda, another which holds one ounce of pulverized borax, another which holds one ounce of litharge, and another which holds 250 grains of salt, and I find them very convenient and much quicker than weighing.

3. These can all be constructed on the assay ton system,

and are much more sensible and convenient than either ounces or gram.

Where only proportions are required the term parts will be used, as will grains or grammes.

The sign for assay ton is A. T. (See article on calculating the assay.)

A UNIVERSAL FLUX.

4. A universal flux may be made up for any and all kinds of ores consisting of the following ingredients and parts, but of course if sulphates are to be assayed without roasting, a due proportion of nitre must be added, and sometimes iron nails may be added with advantage.

$3\frac{3}{4}$ pounds bicarbonate soda.
1 pound pulverized borax.
$1\frac{1}{4}$ pounds litharge.
320 grains of flour.

This proportion, thoroughly mixed, makes an excellent flux for all carbonates or free milling ores, and by using four and one-half to six parts of the flux with one part of the ore will give from 150 to a 200 grain button of lead. If a larger button is required, add a little more of a reducer. I prefer to mix a large quantity of the above flux and keep it in a box all prepared for work. The main thing is to get the ingredients thoroughly mixed, which can usually be done by mixing them pretty thoroughly in a wedgewood mortar, then passing them through a No. 40-mesh sieve. The flux can then be measured or weighed.

MIXING THE CHARGE.

5. The best way is to first measure or weigh out the flux and place it in a wedgewood mortar. Then weigh out the ore, place it on top of the flux, and mix it with a pestle in the mortar. Then pour it into a crucible with a large open tin funnel, covering with salt.

6. The assay should not more than two-thirds fill the crucible on account of the charge swelling when heated.

7. The assay should not be packed or pressed down in the pot; if this be done, some of the substance is liable to be wasted, being blown out by the sudden and forcible escape of the gas.

8. Crucibles which have been used for rich ores should not be used for poor ones; and for important assays they should never be used, new and clean ones always being taken.

9. The same applies to the use of scorifiers. A second-hand crucible will answer for the determination of lead alone very well where traces of gold are unimportant.

ASSAY OF LITHARGE.

10. Whenever a lot of litharge is purchased for use it should be assayed to determine the amount of silver it contains, although litharge is now prepared quite free from silver for assay purposes.

11. The litharge of commerce may be used with advantage, for it holds small traces of silver and prevents it from sinking into the cupel.

12. The readiest way to make the assay of litharge is to place in the crucible:

Litharge	4	A. T.
Flour	1-10	A. T.
Soda	1	A. T.

And cover with salt; melt quickly. When cooled, clean and cupel the button. It is better to make parallel assays as above and determine the amount of silver residue after cupeling. In all assays of ore made of this litharge the amount of silver should be deducted, and it is well to part the silver buttons for gold, which should not be present. If so, the litharge should be rejected.

TO FIND THE OXIDIZING POWER OF NITRATE OF POTASH.

13. It is only necessary to note the weight of the lead obtained in the assay of litharge, and to the same charge add a known weight of nitrate of potash, say 20 or 40 grains, and note the loss of lead or weight of lead button so obtained, and divide the loss of lead by the weight of nitre added, which will be generally be three and a half to one, or, in other words, one gramme of nitre will oxidize three and one-half grammes of lead, generally.

CRUCIBLE ASSAYS.

14. C. H. Aaron divides the crucible assays into two systems, which he says may be applied to any ore, but are best adapted to certain cases. In either case the gold and silver is collected by the means of lead, from which they are afterwards separated.

15. In the first system an excess of litharge is used to oxidize the base metals, except the lead required for the collection of the gold and silver.

16. But most invariably a preliminary assay is necessary; it is a good method, especially in the assay of telurium ores, but otherwise I see no special advantage in it.

17. It is very destructive to crucibles, and expensive in the use of litharge, and I see no special advantage in making the two systems, as much depends upon the intelligence and experience of the assayer.

18. In Mr. Aaron's second system or "nail assay," litharge is not used as a flux for the gangue, but simply as a source of lead, and only so much of it as may be necessary for the purpose of dressing the charge, and obtaining the proper sized button, in collecting the gold and silver in the assay, and this is the only object in assaying all ores.

19. It is advantages that all the base metals, except lead,

should be oxidized. Antimony sometimes passes more or less into the lead, and ores containing much antimony should not be assayed by this method, as it passes into the lead, causing the cupel to crack.

20. If the ore contains copper it will be reduced and contaminate the botton, unless sulphur or arsenic be present to combine with it.

21. In many cases sulphur may be added to a copper ore with advantage, and here again the assayer must be the judge whether it be necessary or not.

22. In all cases of assaying rebellious ores for silver it is best to make a small assay as a preliminary test, then a larger one for a more accurate determination.

23. Ores containing a high percentage of copper pyrites and speiss are better assayed by special methods.

24. Both crucible and scorification assays are in general use, and both have their advocates, but that depends largely upon which they have been taught in learning their business. In Colorado, where the ores are rich in silver, the scorification is best, and I believe generally adopted.

25. On the Pacific Coast the crucible assay is now largely adopted, and I believe gives better results, owing to its allowing larger quantities to be taken for the assay, and hence a larger button of gold obtained for weighing than in the scorification assay, where only a small quantity can be taken, resulting in a small button, which introduces a source of error in weighing and calculating the results.

26. It frequently happens with ores containing sulphurets and copper that a larger button of lead is produced than necessary, and it may be hard and brittle. In all such cases it is better to scorify the lead button down with the addition of test-lead, but in removing the button from the slag great care should be exercised that no particles of the button be lost. It is better to leave some slag with it than suffer any loss.

27. In making up the charge it must be remembered that sulphur, arsenic and anitmony are reducing agents, and that ferric oxide and carbonate act as oxidizing agents.

28. Nitre is the principal oxidizing agent used; but when used a preliminary assay should b e made to know how much to add, as sulphur, arsenic and antimony are reducers, and from the amount of lead they have reduced from litharge it can be easily calculated how much nitre to add to counteract their oxidizing power and give the proper sized button for cupellation. But when nitre is added care should be taken to heat it up gradually during fusion to prevent loss in boiling over, when the fusion is complete. The assay should be allowed to remain in the furnace a few minutes before pouring.

29. In making cupels from dry bone ash, moisten it with carbonate water to make it adherent.

30. The cupels should be dried a few days before using, and they should weigh about 18 grammes.

31. When used they should be placed in the muffle and allowed to become hot before the button is dropped into them.

32. In making a large number of assays use great care to have the cupels marked and numbered to correspond with the ore used.

33. When cupelling commences under a good heat, open the muffle door to allow free access of oxygen, which greatly assists the cupellation.

34. Never let the button cool or freeze in the cupel and attempt to finish it at some other time. Throw it away and do the work over.

EXERCISES.

1. For large work would you use weight or measures for flux?

2. Which is the most convenient and quickest way to work?

3. What can you say of the assay ton?

4. How is the universal flux made up, and what are its parts?

5. How would you mix the charge?

6. How much would you place in the crucible?

7. Would you pack it down, or merely tap it to settle it?

8. In what case would you use a second-hand crucible, if at all?

9. How would you charge a scorifier?

10. How would you first treat a new lot of litharge?

11. What advantage has the litharge of commerce?

12. How would you assay litharge to determine the amount of silver it contains?

13. How would you assay nitre to determine its oxidizing power?

14. Describe the two systems of crucible assays of C. H. Aaron.

15. What is the first system? Explain it.

16. What is the special advantage of this kind of assay?

17. What are the disadvantages of this kind of assay?

18. What is the second system of Aaron?

19. What are its advantages?

20. In the last case, if copper is present in the ore, what would be the effect?

21. When can sulphur be added to advantage in fluxing ore?

22. Why is it best to make a preliminary assay?

23. How would you treat ores containing a high percentage of pyrites?

24. Which is preferred, crucible or scorifiers assays?

25. Why is the crucible mostly used on the Pacific Coast?

27. What must be remembered in making up a charge?

28. Why do you make a preliminary assay before using nitre?

29. How are cupels made from dry bone ash?

30. What should a cupel weigh?

31. How is the muffle prepared for the button?

32. What care must be exercised when making a large number of assays?

33. What is the use of oxygen in cupellation?

34. If the button becomes cool, what must be done?

CRUCIBLE ASSAY FOR GOLD AND SILVER.

1. In ores carrying sulphurets of any kind the beginner should make a series of preliminary assays for the purpose of experiment, and of calculating the amount of reducers or oxidizers necessary for the charges. He will soon acquire the knowledge of the various ores so that he will be able to make the charge without a preliminary assay.

2. An experienced workman can generally judge what to do; the writer rarely makes a preliminary assay, but in doubtful cases dresses the assay according to his judgment, with more or less of the various fluxes according to the nature of the gangue, with an addition of nitre or an extra dose of argole or flour, as the case may be. This is difficult, however, when the ore consists of a mixture, oxidizer and reducer, such as oxide of iron or copper glance.

PRELIMINARY ASSAY.

3. In case a preliminary assay is required, it may be made as follows: Consider whether the ore is likely to be a reducer. (That it contains sulphurets, or an oxidizer; that it carries much red oxide of iron-black oxide of manganese, black or blue oxide, or green carbonate of copper, red lead or chromate.)

4. If it is a reducer, take one-tenth A. T. of ore and five

A. T. of litharge; mix in a crucible, cover with salt, and melt with care that no coal fall in; the weight of the resulting button above O. I. of an A. T. multiplied by 2.5 is the weight of nitre required in an assay of 1 A. T. of the ore; of course if a half-ton assay, take half that quantity, etc.

5. If the button weighs much less than O. 1 of an A. T., the deficit multiplied by ten times the fraction of an assay ton representing the quantity of flour which would bring down one A. T. of lead from the litharge is the weight of flour to be used in an assay of one A. T. of the ore.

6. This can all be done with grains or grammes as well as with A. T. weights. The main point to remember is that one part of nitre is equal to the oxidation of three and one-half to four parts of lead, according to its purity, or an equivalent of sulphurets; and one part of flour reduces from twelve to sixteen parts of lead from litharge.

DRESSING THE CRUCIBLE ASSAY FOR GOLD AND SILVER ORES.

7. The universal flux will generally do for all free milling ores, but for ores carrying a large amount of silver, Mitchell gives one general formula for all gold and silver ores as follows:

Ore	1 part.
Litharge	5 parts.
Soda	1 part.
Borax glass	1 part.

With salt to cover, another part of borax over that, and reducer (argole or flour) or oxidizer (nitre), if needed, in accordance with the indication given by a preliminary assay.

8. The objections apply in a less degree to this as to the exclusive use of litharge as a flux as proposed by Aaron. It is a well conceded fact that in assaying sulphuret ores, a large amount of litharge as a flux is necessary for the col-

lection of all the silver, but not so necessary for the collection of the gold.

9. In a majority of cases two or three parts of litharge is sufficient. It may be necessary to alter the proportion of the other fluxes which the student will be enabled to do by a careful study of their action, remembering always that soda is a flux for quartz, borax for earths and metallic oxides, as is also the glass formed by soda with quartz, and litharge a flux for all.

10. The student will soon learn to rely on his judgment in equalizing the above fluxes to suit his ore for the collection of all the silver. In any event, he can always fall back on his "nail assay" for ores carrying little sulphurets.

11. Ores containing quartz, clay, lime, iron, oxide, with say ten per cent of sulphurets, the following formula will do:

Ore	1	part.
Litharge	3	parts.
Soda	1	part.
Dried borax	1	part.
Flour	1-12	part.

Salt to cover; melt quickly; keep in furnace five minutes after it is well melted.

12. It is important in all cases that the soda and borax be well dried before using to keep from boiling over. If the ore is nearly all quartz the borax may be reduced and the soda increased, or litharge may be used instead.

13. On the other hand, if earthy matters or metal oxides predominate, the soda may be reduced and the borax increased. Borax glass is always preferable.

14. If the button obtained is too large it may be scorified down to a suitable size, say 200 grains, or if very important it is better to make a new assay and gauge your flux accordingly.

15. It is important that the slag be thoroughly oxidized, retaining no vestige of sulphurets.

The different kinds of sulphurets require different proportions of litharge to effect complete oxidation as follows: Only a small part of the litharge is reduced to lead. This is the only case where no nitre is used, and the oxidation takes place with litharge alone. It is an expensive assay, however, and destructive to the crucible, and may be resorted to only where great accuracy is required in the determination of silver.

16. An ore carrying ten per cent of iron pyrites would require fifty parts of litharge, therefore it would be best to use the smallest amount of ore possible to get the true results from it. In any event it is always best to make a preliminary assay with the universal flux.

17. If much copper is in the ore it is better to use a large amount of litharge in the preliminary assay, than to use the universal flux; it will convert the copper into a red oxide with no danger of forming green slag.

18. One way in which to get rid of all difficulty as to the proportion of nitre is to use enough to completely oxidize every constituent of the ore; heat it well, and when flowing smoothly, roll up twenty grains of charcoal in a bit of paper and drop it into the molten assay, throw on top of it a little dry salt; keep it in the furnace five minutes, then tap it and pour it into the mold. The following formula will do for this kind of an assay:

Ore	1 part.
Litharge	8 parts.
Soda	2 parts.
Borax	2 parts.
Nitre	2 parts.
Ground Glass	2 parts.

19. This would require a large-sized crucible; heat gently. When flowing smoothly add one-sixth part of charcoal in small lumps. When the assay flows smoothly under a good heat, shake the pot in the fire and pour.

A still better way in which to make the assay for gold and silver ores containing much copper is to treat the weighed assay sample with hot nitric acid until the copper is dissolved; filter and wash.

20. To the filtrate and washing add hydrochloric acid or a solution of common salt as long as it gives a precipitate; collect the precipitate on a separate filter and wash it. The whole of the silver will be on the filters; that portion which existed in the ore as chloride, iodide, or bromide, on the first filter; the remainder on the second is also converted into chloride of silver.

21. It would not answer to add salt or hydrochloric acid during the treatment of the ore, because the proper quantity cannot be known, and an excess would cause the gold to be dissolved and lost.

22. Dry the two filters with their contents and dress the charge according to the amount of sulphur it may contain by adding nitre if required. In adjusting the flour or nitre it must be remembered that the filters will act as reducers unless they have been completely burnt to an ash in drying, which can be done on a roasting dish in the muffle. Cover with salt and melt in the usual way.

23. Assays made in this way are quite clean, and a larger amount of ore can be used, as it is greatly reduced by the acid treatment.

24. For concentrated pyrites, the following dressing given by Mitchell is suitable and will generally answer:

Ore	1	part.
Nitre	1.7	parts.
Litharge	8.	part.
Soda	1.2	parts.
Glass	1	part.

Cover with salt. The litharge may be lessened as the proportion of soda and glass is increased. Glass is better

to add than precipitated silica, recommended by some, because it is more fusible.

25. The universal flux will suffice in 75 per cent of all the ores that have come to my office in the past ten years. But when not at hand the following dressing will do for most ores:

Ore	1 part.
Litharge	1½ parts.
Soda	3 parts.
Borax	½ part.
Flour	1-10 part.
Iron	3 nails.

Salt to cover. Leave in a strong heat for about twenty minutes. The nails are to free the lead from sulphur. When the ore contains a large quantity of pyrites, add a little nitre; if the ore contains much copper, sulphur or arsenic. The silver may fall short, but the gold will not. In no case should there be any distinct matter above the button, but all the metal sulphides should be blended in a black slag.

26. Any amount of examples may be given for the dressing of the assay, but it is better that the student make his own experiments, and, above all, to learn and know the use of each substance added, and the function it performs.

MELTING IN A CRUCIBLE.

There are so many furnaces in use that it is impossible to give any positive instruction as to the melting. In large establishments the melting is done in a muffle furnace; others in a combination or open furnace with short muffle for cupeling; others by the Hoskins' gasoline furnace. They are all practicable, and the kind to use depends upon the amount of work to be done by it.

27. For small work, where only a few assays are to be

made in a day, the Hoskin's gasoline furnace is the best and cleanest; but in out of the way places, the open charcoal furnace has to be resorted to; but coke is always preferable if it is to be had, and the furnace described in part first, page —, the best.

28. Place your crucibles in furnace in unvarying order so that any given one may occupy the same place according to its number, and it is always a good plan to mark them with red chalk. If any of the assays fail, note the numbers, and make them again after all the others are done. For certainty, celerity and convenience, system is indispensable.

29. In using the Hoskin's gasoline furnaces, covers for the crucibles are unnecessary, and are seldom needed in any furnace except to keep the coals out of the pot; besides, the fusing mass may come in contact with the covers, which would render the assay unreliable.

30. When the fusion is finished in from ten to twenty minutes, rinsed by a swinging movement, and tapped on the molding plate to settle the lead, and the liquid contents poured into a mold, the pot should be completely inverted and tapped against the mold. If the pot is free from adhering lead, and the nails (if they are used) also free from lead, the assay is finished. If lead is shown in globules in either the nails or pot, return the whole mass to the crucible and heat it again, and if the slag is thick or pasty add some borax or carbonate of soda to thin it, and submit it to a strong heat until it is perfectly fluid before pouring.

31. When cooled the assay is turned out of the mold, the button is then beaten out of the slag, hammered into a cube, brushed, marked, and placed in readiness for the cupel. The button must be soft and malleable and easily separated from the slag.

32. The old style three-cornered Hessian crucibles are

best in all cases, if they can be had cheap, for the reason that they cannot be used the second time. The assay is never poured, but cooled in the crucible, the crucible broken, and the button extracted, hammered to a cube, and treated as before stated.

EXERCISES.

1. What is the purpose of a preliminary assay?
2. How does the experienced workman dress the charge?
3. What is the first thing to consider in making a preliminary assay?
4. If it is a reducer, what is added?
5. How is the amount of flour to be added determined?
6. What is one part of nitre equal to?
7. What formula does Mitchell give for all gold and silver ore?
8. What office does litharge perform as a flux.
9. What amount of litharge is generally used?
10. What is the nail assay?
11. What formula is used for ores containing quartz, clay, lime, or iron oxide?
12. How is the soda and borax prepared for use?
13. How do you determine the amount of soda or borax to be added?
14. If the button is too large, how do you proceed?
15. How do you adjust the proportions of litharge?
16. How many parts of litharge would an ore containing ten per cent of iron pyrites require?
17. How does litharge affect copper?
18. How should nitre be added?
19. How may charcoal be added?
20. What is added to the filtrate and washing?
21. Why cannot salt be added during the treatment of the ore?

22. How are the filters reduced to ash?

23. What is the advantage in making assays in this way?

24. What dressing is given by Mitchell for concentrated pyrites?

25. What dressing is used when the universal flux cannot be obtained?

26. What is the most important thing for the student to learn?

27. What furnace is best for small work?

28. What is said in regard to placing the crucibles?

29. When are covers necessary?

30. After the fusion is finished, how do you proceed?

31. How is the button finished?

32. What kind of crucibles are to be preferred, and what is their special advantage?

CHAPTER IV.

Scorification.

1. This method of assaying the litharge required for the fluxing of the ore is made from lead during the operation. Scorification is well adapted for rich ores, but not for poor ones on account of the smallness of the quantity used. Ores containing nickel or tin are best scorified, even if made in the crucible; it cannot be cupelled until scorified.

2. Granulated lead, like litharge, contains a small amount of silver; to determine the amount, take

Granulated lead, 2 to 4 A. T.
A little powdered glass.

Mix in a scorifier; place in a heated muffle and close the door, maintaining a good heat; then open the door and keep a good red heat. Keep the lead fused, and when it is covered by the slag remove from the furnace and pour into a mold.

3. Return the scorifier to the muffle and as soon as the assay is cooled enough to separate the slag, return the lead to the scorifier, and do this several times until a button of proper size is obtained for cupelling; when cupelled, note the weight of the lead, and of the amount used.

4. In assaying the ore a small amount of borax glass is useful in fluxing, unless the gangue is quartz. With an unfamiliar ore it is best to make several assays with different quantities of lead. The following is a general formula for ordinary ores:

Ore ..... 1 part.
Lead ..... 10 parts.

Add a little dried borax unless the gangue is quartz. Mix one-half the lead with the ore and borax in the scorifier; cover with the remaining lead; place in a red-hot muffle. Close the door until the lead is thoroughly melted; open

the door and regulate the heat. The ore will be seen floating on the lead. It soon takes the form of a ring, leaving the lead exposed: this is called the "Bull's Eye."

5. If the "Bull's Eye" does not appear, the assay is a failure, unless it is an oxidizing ore. When the "Bull's Eye" appears, keep it at a cupelling heat, which can be managed by opening or closing the door; add a little more borax if the "Bull's Eye" is covered by the melted slag. When it is perfectly fluid the assay may be poured; if the button is too large, rescorify it to the proper size; then clean and cupel it.

6. If the ore is a sulphuret, omit the borax until the "Bull's Eye" appears; then it may be added. Some claim scorification as the best method, but it can only be so maintained in rich silver ores. The crucible assay for gold is far superior, and more accurate by all odds.

CUPELLING.

The student must have practical experience in cupelling in order to thoroughly understand the operation.

7. By this process the lead is separated from the metal. The cupel should be much heavier than the lead button; it is placed in the red-hot muffle with the cupel tongs and the door closed. When the cupel is thoroughly heated the button is placed in it and the door closed until the lead is well melted, when it is opened to give it air. When the lead appears luminous, the heat must be regulated by means of the ash-pit door, so that the lead smoke may rise to the middle of the muffle. The button gradually becomes smaller and colored spots appear on the surface.

8. These spots are litharge, which sink into the cupel. After a time the heat may be reduced, not so much to chill the button, but just enough to show the crop of small crystals of litharge which form on the cupel.

9. In a short time the button will round up with thin scum on its surface and as it passes off the rainbow-colored rings will be seen to move rapidly and pass off. When this point is reached, the cupel is pushed further back into the muffle, where the heat is greater. Let it remain for a moment.

10. Suddenly the bead becomes still; in a few seconds the cupelling is finished, and when the cupel is drawn near the mouth of the muffle, the bead brightens or blinks. If the bead is mostly gold it is known by its greenish color while fused. The cupel may now be removed from the muffle, cooled and the bead weighed.

11. If the bead is silver, it must be cooled very gradually; if cooled suddenly on the surface, while the cupel is hot, the gas when expelled from the interior, breaks through the solid crust carrying with it some molten silver which will fly off and be lost. This is called vegetating or sprouting.

12. This can be prevented by cooling the bead very slowly, by pushing the cupel back and forth and tapping it on the sides with the tongs.

13. If the button does not brighten, but cools or chills quickly, it probably contains copper, when more lead must be added, and again cupelled; this leaves a bright and clean button of gold or silver, or nothing at all, as is often the case. One of the most important things in cupelling a number of assays at one time, is to keep your cupels from getting mixed or changed.

14. Each cupel should be numbered to correspond with the assay. Some assayers never mark their cupels, but trust to their memory, or the location of the cupel in the muffle. I think it a bad practice, for the memory is very faulty, especially in removing cupels from the muffle. When one is finished and taken from the muffle, another

may take its place; this often accounts for many false returns in an ore assayed.

A mistake of this kind might give a good return for a man's ore that had nothing in it, and a poor return for an ore that was really rich.

15. I always mark my cupels on the side with an old case knife to correspond with the number and owner of the assay on my record book, and each number when cupelled takes its allotted place on the tray.

16. Another point in cupelling silver buttons is to guard against excessive heat. Never go away and leave your assays in the muffle to take care of themselves. Silver buttons, when uncovered in a strong heat will sublimate. In such a case your silver may be found clinging to the roof of the muffle. Watch the assays carefully from beginning to end.

Practice makes perfect. Let the student take some proof silver, wrap it up in lead, cupel it, and note the loss, until he finds out what he can do.

17. On removing the cupels from the muffle, place them on a tray in their regular order, and carry to the anvil. The large beads are seized by the plyers, laid on the anvil, and after being cleansed with a stiff brush are flattened with a small smooth hammer. Each bead as it is cleansed is placed on a watch glass bearing the set, and number of assay placed on the disk of paper pasted to the convex side so that it can be read through the glass.

18. The glasses are arranged on a tray similar to the cupel trays.

Some assayers have a bad practice of placing the bead back on the cupel from which it came and carrying them to the scales in that manner. It leads to occasional loss. Sometimes the bead is carried some distance in the plyers to be weighed, and is liable to be dropped on the floor,

where a very small bead could not be found. The tray with the watch glass containing the bead on it can be placed close to the scale pan of the balance, where the loss of the bead is almost impossible, and without dirt, as is the case with the cupel.

19. The weight of the bead is noted in a book kept for the purpose, opposite to the set and sample number; under the weight is noted the correction due to silver in the litharge or lead used in the assay, which being subtracted leaves the net weight of the precious metal obtained from the ore. There is always some silver lost in the cupelling, but it is not worth while to make a correction for it, except in a bullion assay.

WEIGHING THE BEAD.

20. Again I must call the attention of the student to this most delicate instrument, the balance. By it alone the result of an assay is determined, and too much care cannot be taken in weighing the bead and adjusting the balance.

21. First see that your balance is properly adjusted and that no dust is on or about the beam. If so use a camel's hair brush to clean it.

Place the bead on the left-hand pan, because the right hand is then conveniently employed in adjusting the weights on the right-hand pan, while the left operates the turnkey by which the supports are raised or lowered.

22. When equilibrium is nearly attained, the case must be closed, because the slightest current of air, or even your breath will disturb the action of the balance. It is here that the great convenience of the riders and carriers are realized. The weights having been adjusted to the ten or thereabouts, the case is closed and the operation finished with the rider, by moving it to the right or left until perfect equilibrium is attained.

23. When riders are not used, the fractions of a unit

may be estimated by the oscillations of the pointer. Many new beginners suppose the ivory scale indicates 1-10 of the units of weight of grains or grammes, but it is not so.

24. The divisions are only intended to mark the range, swing, and rest. Range is the total movement of the index, counted in divisions of the arc (called vernier by some), and may extend to each side of zero; again the pointer may move to either side and not return to zero. It has no value as an indication of the amount of preponderance, but from it we calculate swing and rest.

Swing is the excess of movement to one side or the other of zero, caused by the preponderance of weight in one of the pans; hence the balance in equilibrium will have range.

Swing is equal to range when one extreme of range is zero; it is the difference of the distances from zero when the pointer goes to each side of zero, that is, when the signs of the distances are opposite; it is the sum of the distances when the signs are similar.

25. Range is a matter of observation only. It may be increased whenever desired by a waft of the hand, a slight current of air against either of the hands, after which the case may be closed, and after a few moments begin the observation.

"Range (an average) is 8×-3, as the signs are opposite, swing is the difference, $= \times 5$: rest is $\times 2\frac{1}{2}$. Again: range is -8×3: the signs are opposite and the swing is -5; rest, $2\frac{1}{2}$.

"Weighing by oscillation is useful only when riders are not in use. It avoids handling the lesser weights and finishes with the case closed.

"If you can understand the foregoing method of obtaining the true swing, arrange your balance so that if not in perfect equilibrium, any swing it may have shall be to the right; then in each weighing subtract the previous from the present swing. The remainder will be the true swing.

"I have heard some learned talk from beginners about weighing down as low as three cents per ton in gold, when in fact $10.00 per ton would be nearer the truth.

26. "It will take an hour to adjust the best balance made to weigh as close as 15c per ton. It is no funny job. It can only be done by the method I have here pointed out—by range, swing, and rest. If a man is going to be an assayer, he must learn the business, and not learn just enough to expose his ignorance of it."—C. H. Aaron.

PARTING THE BEAD.

27. Beads obtained from ore always contain more or less silver, and are parted by boiling in nitric acid. In order to separate them completely, it is necessary that the alloy shall contain at least twice as much silver as gold, and that it be flattened to a thin sheet unless it has as much as three parts of silver to one of gold. In a large proportion of silver the gold is left in the form of dark powder. Beads obtained from an ore frequently contain sufficient silver for a successful parting. In small beads it is a good plan to add a known weight of pure silver to collect the gold and keep it from sinking into the cupel.

28. When the bead is yellow and gold predominates it requires the addition of two to two and one-half parts of silver.

If, on attempting to part the bead, it is found to be blackened, but not much affected by the acid, it requires two parts of silver.

29. This addition of silver is called inquartation. For this purpose some test silver cut into small pieces is kept on hand in a small box in the scale drawer.

30. For small beads the silver need not be weighed, but select a few pieces which are known to be sufficient, it matters not if it is four times as much as the gold.

The silver and bead may be folded in a small piece of thin sheet lead and cupelled, the bead cleaned as before, flattened on the anvil, parted, washed, and "cupped," heated to redness, and weighed. The acid for parting need not be strong; 32 Baume is sufficient, and will be less liable to lumping or breaking up the gold than stronger acid.

31. The test tube is best for parting. Heat it with a spirit lamp or gas flame gently. When the parting is completed, and the gold has collected together, the acid is poured off. The tube is then filled with pure water and the gold allowed to settle, when the water is poured off. The tube is again filled with water and held between the fingers of the right hand. A dry cup is inverted over it and retained by the thumb. By turning the wrist the tube is inverted and the gold settles through the water to the bottom of the dry cup which is now right side up, the mouth of the inverted tube within it.

When the gold is settled the dry cup is held by the left hand, the tube by the right, and the latter is carefully raised, allowing air to enter and the water to escape, nearly filling, but not overflowing the cup.

32. Allow the disturbed gold to settle; work the mouth of the tube up on the edge of the dry cup and scrape it off quickly, not allowing any of the water to enter the dry cup to throw the gold out.

The cup now contains the water and the gold; tap it to collect all the gold in one body; then draw the water off with the aid of a glass rod, draining it as much as possible; then take it to the muffle on the tray and place therein with the tongs; heat it to a redness; again place on the tray, and when cooled, carry it to the balance for weighing in its regular order.

The weight of the gold noted, from the weight of the bead from which it is substracted, leaves the net weight of the silver.

33. Frequently the gold ores from one mine where the fineness of the bullion is well known and the value per ounce determined, the bead may not be parted, but the value per ounce be calculated according to its known value, say at $16.00 or $17.00 per ounce, or whatever it may be; this saves much time and labor in parting the beads.

CALCULATING THE ASSAY.

34. On weighing, the gold and silver from an assay are always reported, as before stated, in units and decimal fractions of the units of the system of weights used.

As a ton of 2,000 pounds of ore contains fourteen million grains, it is easy to calculate by proportion, that if one ounce troy (480 grains) contains 1-100 of a grain a ton would contain .6060 ounces, which, if gold, would be worth $12.40; if silver, 77c or $1.29 per ounce.

35. These figures are, therefore, constant factors, and multiplying the weight of metal obtained from such an assay in units of the system by these factors gives us the ounces in a ton, or the value in dollars and cents.

36. The best method is to take such a weight of ore as contains as many points or units of the assay set as there are troy ounces in a ton of 2,000 pounds, that is, 29.1666× such a weight, is called the assay ton, and the sign for it is A. T.

In the grain system, that is when the bead is weighed in hundredths of a grain and fractions thereof, the ton consists of 291.67 grains and each point of bead weight, gold or silver, corresponds to one ounce of the metal in a real ton of the ore.

37. In the gramme system, where a point is a milli-

gramme, the ton consists of 29.167 grammes, and, as in the other case, each point of bead weight corresponds to one ounce in the real ton of the ore. This, of course, can be halved or quartered to suit.

38. An ounce of gold is calculated as worth $20.67 per ounce, and an ounce of silver is calculated at $1.2929, but this is only the assay value of silver; at present it is worth less, and the value thus found must be discounted according to the market value; but it is best to report the silver in ounces per ton alone.

EXERCISES.

1. To what kind of ore is scorification particularly adapted?

2. How would you make a charge of granulated lead to determine the amount of silver it contained?

3. If the lead button was too large to cupel how would you treat it?

4. How would you make the dressing of an ore assay, and what would you add? Would you add borax if the gangue was quartz?

5. Suppose the "Bull's Eye" did not appear, what would you do?

6. In what kind of ore might the borax be omitted?

7. What is the philosophy of cupellation, and why should the cupel be heavier than the lead button?

8. When spots appear on the surface of the button, what does it indicate?

9. When the button rounds up at the close of the cupellation what is indicated?

10. How does the bead act near the close of the cupelling?

11. How would you cool a bead that was all silver?

12. How can the vegetating be prevented?

13. What is indicated by the non-brightening of the button? What would you do?

14. How would you prevent the cuples getting mixed, or the numbers changed in the muffles?

15. How would you mark your cuples?

16. Do you need a high heat in cupelling?

17. In removing the cupels from the muffle, how would you treat the beads?

18. What are the watch glasses used for?

19. How is the note-book used?

20. What is the most important instrument in the assayer's office?

21. What is the first duty in weighing the bead?

22. Describe the process of weighing the bead.

23. Of what benefit are the riders, and when are they used?

24. What do divisions on the Ivory scale denote, and for what are they used?

25. Describe the range, spring, and rest.

26. How close can gold be weighed, and caalculated in dollars and cents?

27. Is gold found pure or as an alloy, and how would you put it?

28. If, on attempting to part the bead, it burns black, what is indicated, and how would you proceed?

29. What is the addition of silver called?

30. How is silver added to small beads?

31. What is used to part the beads?

32. Describe the process of parting in full.

33. When may the parting of the bead be dispensed with?

34. How would you report an assay of one ounce of ore in one one-hundredth of a grain?

35. What is the constant factor for one ounce, and for one-half ounce?

36. What is the best system to use?

37. When A. T. is used, what does one point indicate?

38. What is gold valued at per ounce, and what silver?

LABORATORY TEST OF EXTRACTING GOLD BY THE CYANIDE OF POTASH SOLUTION.

The precipitation of gold from cyanide solution by zinc shavings has been more generally used than any other process. It appears on the face of it to be the simplest method that could be devised when properly done, and gives better results than any other in use. Yet many who have described the application of the cyanide process have not given sufficient weight to the complete precipitation of the gold from the solution. It is not so simple a matter as some are led to believe, to completely precipitate all the gold from the potassium-aurocyanide solution.

1. Although the action of zinc on gold solution is a very simple substitution of gold from the the zinc in accordance to the following equation:

2. $2Au, K, Cy_2 + Zn = K_2 Cy_4 + 2Au$

Its completeness seems to depend entirely upon a slight excess of cyanide of potassium being in the solution.

3. It must be remembered that no ores containing zinc of any kind, can be treated by this method.

4. Therefore it is always best to test all ores for that metal before submitting it to the cyanide solution, especially if the ore is a sulphuret.

5. Take one pound avoirdupois—or any number of pounds—of the fine pulverized ore and place it in a heavy, wide-mouthed glass jar.

6. Weigh out seventy grains of the commercial cyanide of potash to each pound of the ore used; dissolve it in water of an equal weight of the ore, pound for pound, and pour

it into the glass jar with the ore; shake it until the ore is saturated; cork it and set it aside for two days, occasionally agitating by shaking.

7. If the gold in the ore is very coarse allow it to stand a week before leaching it out, as it takes time to disolve coarse gold.

8. When sufficient time has elapsed to dissolve the gold prepare a large funnel, fitted with a coarse filter, and in the bottom place a half-ounce or more of fine zinc shavings; on this fit another coarse filter paper, upon which decant the aurocyanide solution, and let it percolate through the zinc shavings into a vessel; add a little water, wash the pulp and again decant on the filter. Do this several times until the pulp is well leached.

9. Then take off the second filter with the sediment and pour the aurocyanide solution over the zinc shavings five times; it will percolate through the shavings, and the gold and silver will be found to have replaced the zinc to the full extent of the metal which was in the ore.

10. Now plug up the outlet of the funnel, and pour over the zinc shavings a weak solution of sulphuric acid which will dissolve the zinc, leaving the gold on the filter; remove the filter from the funnel, cut off all not containing the gold, dry, and burn the filter to an ash; envelope the gold and filter-ash in a sheet of lead and cupel; weigh the gold obtained, and calculate the value per ton from the amount of ore used.

11. If doubts exist as to whether all the gold is extracted from the solution, add a little chloride of zinc to the leached solution; let settle; decant and filter, and make an assay of the residue.

In order to test the above reaction, I make up a solution of potassium aurocyanide with about one per cent of metallic gold and no free cyanide. A solution was made from

this so as to contain 0.1 per cent, or about $600.00 per ton, gold. I treated this with a piece of clean, bright zinc (common commercial zinc), which is always used in practice. This was immersed and agitated in the solution for 45 hours, when it was taken out and carefully weighed; but not a trace of gold, to the amount of a hundredth part of a miligram, could be detected, and after dissolving it in weak sulphuric acid, there was still not a trace of gold to be found. This made me think the gold could be extracted from the ore, but not from the solution. Any one trusting to this would naturally throw it away, when at the same time it contained $600.00 per ton. I next prepared some zinc shaving by scraping it with a sharp knife, and placed it upon a filter paper in a funnel, then placed a second filter over the zinc shavings, so the solution would slowly percolate through the zinc, and, after decanting the solution through these shavings five times, was able to collect the whole of the gold on the zinc, where it seemed to replace the zinc, for, when the zinc was completely dissolved in weak sulphuric acid, I found the gold in the same form as the zinc shavings were themselves. This was all done in 24 hours. It was a mystery to me why the gold should precipitate on the zinc shavings, and not on the bright zinc plate.

The indications point to polarization, so well known in electrolytic work. But whether, on the bright zinc plate, the invisible trace of films put a stop to further action by preventing contact or producing an opposite electric force, is a question.

There is no doubt of the tendency of potassium-aurocyanide to split up into K. Cy. and Au. and C., which is assumed in the reaction by substitution. Then, again, there is a tendency to split up along another line, viz., K. and Au. Cy., like an acid reaction. Now, if this be the case

in the presence of zinc and water, the water will be attacked by the potassium and the Au. $Cy._2$ will be attacked by the zinc, forming zinc cyanide and metallic gold. It can only take place by the condition of the polarization on the surface of the zinc, owing to the film of hydrogen set free on its surface; if this is so, it is very clear why the zinc shavings will act when the polished zinc plate does not, the zinc shavings having a larger number of ragged edges, which causes the escape of the hydrogen gas and allows the reaction to go on. When the reaction once sets in, there is a further reaction between the caustic potash and the zinc cyanide, which dissolves a part of the latter. The main point would be: Is hydrogen formed on the surface of the zinc plate, or is it absent? It is well known that when the zinc is forming on zinc shavings hydrogen gas is set free. It does not form at first, but upon shaking the zinc shavings fine bubbles of gas escape and can be easily collected.

ASSAY OF TIN ORE.

There are many methods of conducting the fire assay of tin ores, but none excel a cyanide flux as a reducer, although for many ores carbonate of soda and borax will do as well.

1. Take 200 grains or twenty grammes, or any other convenient quantity of finely pulverized ore (and it is always advisable to make two independent parallel assays with the view of having a control), and take the highest result obtained upon which to place reliance, since the error, if any, must be on the side of the loss, rather than the excess.

2. Take the old Hessian crucible if at hand, or any clay crucible will do. In the first place ram into the bottom of it a small charge of powdered cyanide of potassium sufficient to form a layer of about a half inch in depth.

3. The weighed quantity of tin ore is then intimately mixed with four or five times its weight of powdered cyanide, and the mortar rinsed with a small quantity of the flux which is laid on top of the mixture.

4. The crucible is then heated in a moderate fire for ten minutes with a steady fusion heat so that it will not boil over, until it flows smoothly; cool; break the crucible, and extract the button of tin which will be silvery white; weigh and calculate the percentage of tin.

5. Assay of Tin Ores Which Contain Arsenic, Sulphur, Tungsten (Wolfram).—In all such ores it is necessary to remove them before attempting to obtain the tin in a pure state, by fire assay.

6. The best method of treating all such ores is to decompose them by nitro-hydrochloric acid (aqua regia) at the boiling temperature. The oxide of tin alone is not affected by it.

7. Take 400 grains or more of the impure tin ore pulverized; place it in a boiling flask, and add one-half ounce of hydrochloric acid and one-half ounce of nitric acid. Heat gently for half an hour, then boil until the greater part of the mixed acids are evaporated.

8. This will cement the sulphur and arsenic into sulphuric and arsenic acid. The iron and manganese will become soluble.

9. The tungstaic acid will remain in the insoluble state with the oxide of tin and silica.

10. Allow the flask and contents to cool; add water and let settle, and decant. Continue doing so until the water passes off tasteless.

11. The insoluble matter in the flask is now oxide of tin, silica and tungstaic acid.

12. To remove the latter digest for one hour at a very gentle heat with one ounce of solution of caustic ammonia

with occasional agitation; add water and van the remainder to separate silica. Nothing now remins but the oxide of tin, with a little silica. This is dried and assayed as first stated with cyanide of potassium.

13. Oxide of tin alone, the protoxide, in the state of hydrate, lights and burns like tinder and becomes peroxidized.

14. Wolfram is a tungstate of iron and maganese (Fe Mn) W. O_4 in which the proportion of the two metals is variable, and generally associated with tin ores.

15. To determine the tungstate, the finely powdered mineral is heated with acqua regia until it is completely decomposed. The solution is evaporated to complete dryness over a water bath, water added, and the manganese and ferric chloride filtered off.

The residual tungstic acid is washed with alcohol, dissolved in ammonia, the solution filtered from any residue, evaporated to dryness in a capacious porcelain crucible, gently heated to expel ammonia and ignited by contact with the air.

16. The tungstic oxide is then weighed; it should have a pure yellow color free from any greenish tint.

There are several methods of determining the amount of tin and tungsten in an ore by volumetric analysis, but for all practical purposes the above is sufficient.

EXERCISES.

1. What is the philosophy or reaction of gold on zinc in a cyanide solution?

2. State the equation.

3. What depends upon saving the gold?

4. For what purpose would you test all ores before treating them with cyanide?

5. State the amount and arrangement of ore used for a charge.

6. What strength of cyanide is used, and how is it prepared?

7. How is coarse gold treated?

8. What is the method of treating it?

9. How many times is the zinc treated with the auro-cyanide solution?

10. How is the zinc separated from the gold?

11. When doubts exist as to whether all the gold has been taken from the solution, how is the fact determined?

EXERCISES.

1. How much ore would you take for a tin assay, and how would you control it?

2. What would you use for a flux?

3. How would you arrange the charge in a crucible?

4. How would you arrange the heat at first?

5. What are the principal constituents of a base tin ore?

6. What is the best method of treating a base ore of tin?

7. What acids are used, and how much of them?

8. What are the acids converted into?

9. How, and in what form is the tungstate left?

10. At what point would you decant and wash the contents of the filter?

11. Of what is the residue on the filter composed?

12. How is it removed and treated?

13. How many oxides of tin are there, and how converted one to the other?

14. What is the wolfram? Give the formula.

15. What ores is it associated with, and how is it determined?

16. What is the appearance of the tungstic acid, and what is it called when dried and weighed?

COPPER ASSAY.

1. The fire assay of copper is never perfectly accurate, although many kinds of copper ores can be assayed within one per cent of the truth by it, and it will always do for a prospect assay, if above fifteen per cent in copper.

2. Poor ores and all which contain lime or baryta and sulphur had best be submitted to a matte smelting, which gives a richer product to work on, and in the second place it removes calcium or barium sulphate, which causes a loss.

3. Ores containing less than eight per cent of copper, C. H. Aaron recommends the following charge:

Ore	400 grains.
Borax glass	400 grains.
Flour	20 grains.
Sulphur	10 grains.

Mix in a wedgewood mortar; put in a pot and cover with salt; over that again put 400 grains of borax glass. If there is any sulphur in the ore omit the flour.

4. If there is any lead in the ore add three nails. Melt slowly and finish with a strong heat; when melted let it cool in the crucible; separate the matte from the slag, and from the lead if any, and reserve it for further use.

5. Ores which are rich and combine with baryta, lime, gypsum, heavy spar, or sulphurets of any kind is best converted into a matte by the following charge:

Ore	1 part.
Borax	1 part.

6. Add sulphur if there is none in the ore; place in the crucible; cover with salt and borax, and add nails if lead be present; melt down, cool, and reserve the matte for the determination of copper.

RICH SULPHURETS OF COPPER WITHOUT LEAD, LIME OR BARYTA.

7. These include the mattes from the preceding as well as the natural ores. Pulverize the ore, roast it in a roasting dish with a little charcoal, beginning with a low heat and raising it gradually to a bright redness, stirring with an iron wire occasionally.

8. When no more odor is perceptible from the red-hot ore, cool and grind again.

9. Take notice if any arsenic is present or not; if so it has an odor like that of garlic.

If arsenic is present add a little more charcoal; re-grind and continue the roasting until expelled.

10. Then place on the ore a little carbonate of ammonia, mix it with the ore and heat; it will remove the last traces of sulphur. The ore is now in the following class of

RICH OXIDIZED ORES.

11. The ore may be a natural oxide; if so it must be weighed and calcined by heating to redness in a roasting dish; mix in crucible the following charge:

Ore	1 part.
Soda	2 parts.
Argol	1 part.
Lime	$\frac{1}{4}$ part.

In place of soda, cyanide of potash may be used with good advantage. If much quartz is in the ore add a little powdered iron ore;mix well in wedg wood mortar. Place in crucible which should be more than two-thirds full; cover with salt and borax glass.

12. Heat very slowly at first to a dull redness for 10 minutes, then give it a high heat; remove from the fire qpickly, wash the pot with the slag, tap to settle all globules; cool and break the pot. The copper will be found in a single button.

13. If the button is malleable and of a good color, it may be weighed and the percentage calculated. But if the button is black or gray it must be refined by cupellation.

REFINING OF PURE COPPER BUTTON.

14. Place the button in a highly-heated cupel with an equal weight of pure copper on another. Add to each one-tenth part of lead and close the muffle door.

When the buttons are well melted, open the door to admit air, and the refining begins.

15. The heat must be higher than for a silver assay, and the final brightening is much less vivid. The moment the lead leaves the copper it solidifies. Continue this operation by adding the one-tenth lead and cupelling until the copper is purified; cool by placing the cupel and button in cold water. Clean and weigh the buttons, and to the assay button add as much as the pure button has lost, and calculate the percentage.

16. If gold and silver is suspected to be in the ore, add lead and continue cupelling until all the copper is completely cupelled off. Then weigh the resulting bead.

VOLUMETRIC METHODS.

17. There are many methods of determining copper volumetrically, that is, by the volume of a re-agent which is found to be necessary to produce or complete a certain effect in the suitably prepared solution; the best in my opinion, and the one most commonly used, depends on the fact that the blue ammoniacal solution of copper is discolored by a solution of potassium cyanide that is generally known as the

CYANIDE PROCESS.

18. Take one gramme of pure copper, dissolve it in nitric acid; add ammonia until the p.p. at first formed is re-

dissolved to a blue liquid; and then filter off the precipitate of iron; add water to make about 200 c.c. in a boiling flask. Charge a Mohr burette with a solution of potassium cyanide made by dissolving one troy ounce in five and a half fluid ounces of water, and filtered if necessary.

19. Run the liquid from the burette into the blue solution of copper, stirring it with a glass rod, until the blue color becomes faint and purplish; continue cautiously adding the cyanide, little by little, finally drop by drop, with intervals between until only a faint tint remains which disappears in a few minutes, leaving the liquid colorless; observe how many c.c. of the cyanide has been used by the mark on the burette, and note the number.

The cyanide solution is thus titrated; that is, it is known what volume of it corresponds to one gramme of copper in the assay. This is called the standard cyanide solution and should be kept in a dark-colored bottle, stoppered.

20. To make the assay of the ore, take one or two grammes, more or less according to the richness of the ore, and make an acid solution by one of the methods previously described, or by nitric acid alone. (Some take pains to expel the nitric acid by addition of zinc or evaporation, but it is not necessary). Add ammonia in excess, and heat to boiling for some time; filter off the iron, silica, etc., and wash with water until it passes through colorless.

21. The entire volume of the solution, including the washings, should not be more than 200 c.c.

When quite cold add solution of potassium cyanide from the burette precisely as in titrating the standard solution, noting the quantity used.

22. To determine the assay is now only a matter of proportion or the "rule of three." For instance, if one gramme of pure copper required 80 c.c. of cyanide solution to clarify it, and one gramme of the ore required 30 c.c.,

then 80:30::100:?. the copper in the assay =37.5 per cent.

23. The interfering elements in this process are manganese, which can be obviated by adding a little carbonate of ammonia.

Arsenic also interferes, but can be overcome by adding a little of the magnesia mixture.

24. Nickel, cobalt, and zinc, are all fatal to the accuracy of the process. If they, or any of them are present, it is better to precipitate the copper by means of a platinum dish.

25. Pour the solution into a platinum dish of known weight, add a piece of pure zinc; the copper is precipitated on the dish, to which it adheres, making it easy to wash. The whole of the zinc is to be dissolved, acid being added if necessary, until no more bubbles are seen.

26. The copper is washed, dried and weighed on the dish. The weight of the dish deducted leaves the weight of the copper, which is removed from the dish by means of nitric acid, which does not attack the dish.

EXERCISES.

1. Is the fire assay of copper correct?

2. How should poor copper ores containing sulphur, baryta, or lime be treated?

3. What is Aaron's method for ores less than 8 per cent in copper?

4. Should nails be added?

5. How would you treat rich ores containing lime, baryta, or gypsum?

6. Would you add sulphur and nails to make a matte?

7. How would you treat rich sulphurets of copper without lime or baryta?

8. How would you know when all the sulphur was expelled from the ore under heat?

9. What is the odor of arsenic?

10. Why add carbonate of ammonia to finish a roast?

11. How would you make a fire assay of rich oxide ores?

12. How would you arrange the heat?

13. What are the indications of a good fire assay?

14. How would you refine a copper button?

15. What kind of a heat is required in refining a copper button?

16. If gold and silver are suspected in the button how would you treat it?

17. What process is mostly used in the volumetric system of copper assays?

18. How would you prepare a standard solution of cyanide of potassium?

19. How would you titrate it? Explain it in full.

20. How would you make the assay with it? Explain in full.

21. What amount of solution is best for titration?

22. How would you calculate it? Give an example.

23. What are the interfering elements, and what are the remedies?

24. When nickel, cobalt, or zinc is present in the ore, how would you treat the solution?

25. Explain the process of precipitation and calculation of the assay in a platinum dish.

26. How would you remove the copper from the platinum dish?

LEAD ASSAYS.

1. Numerous methods have been proposed for the determination of lead, by the fire assay, gravimetric, and volumetric systems, but the fire assay is the one most extensively used in the United States and elsewhere for the determination of lead in purchasing ores.

2. The advantages are the ease of execution and the large number of assays which can be made in a short time.

3. The disadvantages are that all the lead is seldom reduced, and the buttons are seldom pure, and may contain more or less antimony, tin, copper, bismuth, iron, or zinc, yet the fire assay is the only method which the western smelters will accept for a basis for the purchase of ores. H. Van F. Furman says the fire assay of lead ore is too high; Mr. C. H. Aaron says that it is too low.

4. But beyond doubt, the gravimetric determination is the most accurate method of all, but it takes time, and very careful manipulation.

5. The fire assay is most generally practised in Colorado. For ordinary ores the crucible is used, taking one part of the ore with four parts of the lead or universal flux, mixed in a clay crucible and covered with borax, and fused in a muffle furnace. The time of the fusion with a good heat is from 15 to 20 minutes. In the case of sulphide or base ores two or three nails are used in the charge. When the fusion has become quiet the crucible is allowed to remain in the muffle three or four minutes, when it is drawn out and poured into a mold.

As soon as cold the button and the slag are removed from the mold, and the button extracted from the slag by pounding with the hammer.

6. The button, which should be malleable and soft, is flattened on the anvil. If brittle, it contains copper, antimony or iron. The slag should be vitreous and brittle, and should contain no shots or globules of lead. Where great accuracy is required, it must be made in duplicates which must agree within one-half per cent.

7. The best method I have found for the fire assay of lead ore, where the ore is a pure sulphide of lead, is to use no other flux than pure bicarbonate of soda, taking three

parts of the soda to one of the ore and covering it with salt. Nails are not required and the button is always found malleable and clean.

8. If the ore is oxidized or carbonized at all use a little argol (crude tartar) and cover with salt.

The sulphur has a greater affinity for the soda than it has for the lead; therefore, under the action of heat it leaves the lead and combines with the soda to form sulphate of sodia with the slag.

9. To ores which contain copper oxide or carbonate, and not enough sulphur to combine with the copper so as to keep it in the slag, some sulphur may be added for that purpose, or the weighed assay may be boiled in nitric and sulphuric acid, which will dissolve the copper, leaving the lead as an insoluble sulphate; the liquid must be diluted with water and filtered off; the residue dried, dressed and smelted for the lead.

10. A general formula for the dressing of lead ores is

Ore	1	part.
Soda	3	parts.
Flour or argol	1-10	part.
Borax	½	part (nearly).

Mix in a crucible, add several nails and cover with salt.

11. If the ore is a complex sulphuretted one, keep in the fire twenty minutes after frothing has ceased.

Pure carbonate of lead (crucite) does not require nails, and can be melted and poured quickly.

12. The lead button can be cupelled for precious metals like the gold and silver ore assays, and the value calculated accordingly.

There are several volumetric methods of determination of lead in ores by standard solution, but as so many methods might tend to confuse the student I shall confine

myself to one wet assay as recommended by C. H. Aaron, viz:

13. "Take a weighed quantity of the powdered and dried ore with a mixture of nitric and sulphuric acids (a little hydrochloric acid may be added if necessary), in a covered casserole or porcelain dish.

14. "Boil until the ore is decomposed and until dense white fumes of sulphuric acid are evolved while still some liquid remains (otherwise add some sulphuric acid). Cool; add water cautiously; digest warm for a short time; filter, and wash with water to which a few drops of sulphuric acid have been added. After draining, remove the filter, with its contents, from the funnel to a porcelain dish or beaker; unfold, and lay it flat on the bottom.

15. "Cover it with ammonia and add acetic acid until the mixture distinctly reddens blue litmus paper. Keep warm for half an hour, stirring occasionally. Decant the liquid upon a filter; wash the residue in the dish several times by decantation.

16. "Add to the water at first a little ammonium acetate made by mixing ammonia and acetic acid, with care that the acid predominates; finally transfer all, including the original filter, to the filter and complete the washing; the filtrate contains the lead in solution and may also contain lime, not baryta nor strontia.

17. "To the filtrate add dilute sulphuric acid as long as it produces a p.p. Heat; settle; filter; wash with sulphuric acidulated water, finally, once or twice, with pure water, or, better, with alcohol.

"The lead is now on the filter in the form of sulphate, as it was after the first filtration, but freed from impurities. Dry it on the filter; transfer it to a small porcelain crucible of known weight or counterpoise; burn the filter; add the ashes to the p.p. and moisten them with a drop of sulphuric

acid; heat nearly to redness, cool and weigh in the crucible. If very particular, burn another filter of equal weight with the first, moisten the ashes with sulphuric acid, and put them on the weight pan when weighing; a convenient way in which to manage this is to let the counterpoise, or part of it, be another crucible in which the second filter may be burned and the ashes treated as described.

18. "Unless for very particular work, the lead sulphate may be weighed on the (tared, etc.) filter, after drying at 248 Fahr. (in the air-bath). The lead sulphate contains 68.32 per cent of lead.

19. "A modification of the process is as follows: Treat the ore with acids as above; wash thoroughly with sulphuric acidulated water, so as to remove all lime; dry the insoluble matter, consisting of lead sulphate, silica, barium sulphate, etc., and weigh it; extract the lead sulphate by means of ammonium acetate as above; wash, dry and weigh the residue. The loss represents lead sulphate, and, multiplied by .6832, gives the weight of the lead. As calcium sulphate is soluble in ammonium acetate, great care must be taken to insure its absence from the first-weighed residue by thorough washing."

EXERCISES.

1. What method of lead assay is mostly practised in the purchase of ores?
2. Why is it especially advantageous?
3. What are the disadvantages?
4. Which is the most accurate of all?
5. What method is mostly adopted in Colorado? Describe the process.
6. How would you treat the lead button? If it is brittle what does it indicate?
7. What is the best method of obtaining pure lead by the fire assay?

8. If the ore is an oxide or carbonate of lead, how would you mix the charge to flux it?

9. How would you treat the lead ore if it contained copper?

10. What is the general formula or dressing for a lead assay?

11. How would you treat a complex sulphuretted ore?

12. How would you cupel the lead button for precious metals?

13. Describe the treatment of the ore to make the wet assay for lead.

14. What is the effect of adding sulphuric acid?

15. What is the effect of adding acetic acid?

16. How is the acetate of ammonia added?

17. In what form is the lead collected on the filter?

18. What percentage of lead is the sulphate of lead so obtained?

19. In the modification process, why multiply by .6832 to get the percentage of lead? Explain it.

DETERMINATION OF IRON IN AN ORE.

1. The ores of iron most commonly used for the extraction of the metal, and as a flux for smelting furnaces, are the magnetic oxides, red and brown hermatite, specular ore, or spathic ores, and many times the amount of iron in a pyrites is required.

2. Where the iron alone is required it is best to first determine the moisture.

3. Then the silica, an insoluble residue, and lastly the iron.

4. Take two or three grammes of the finely powdered ore, place it in a platinum dish, heat it to 100 c.; and weigh until the weight is constant. The loss in weight is the moisture.

5. The ore is now oxidized with fuming nitric acid in

the dish. Add a few cubic centimetres of strong sulphuric acid, and evaporate to dryness.

6. The residue is now dissolved in hydrochloric acid, water added, and allowed to stand; then filtered into a boiling flask, and washed.

7. The indissoluble portion on the filter consists of silica and gangue, which should be well washed with hydrochloric acid and water, dried, cooled and weighed, and this is the silicates.

8. To the filtrate add ammonia in excess.

9. Also a few drops of yellow sulphide of ammonia; boil; decant repeatedly on the filter; finally bring the whole precipitate on the filter and wash with hot water.

10. Redissolve the precipitate by pouring hydrochloric acid on it in the filter; wash the filter with hot water, using a clean beaker to receive the filtrate. Again add ammonia and precipitate; boil; decant on a clean filter and wash as before.

11. The alumina, if present in the ore, will be precipitated with the oxide of iron on to the filter, which can be separated from the iron by boiling the precipitate.

12. To boil it, use a strong solution of potash for some time in a thin porcelain dish which dissolves out the alumina leaving the oxide of iron which may be caught on a filter, well washed with hot water; dried to 212 f., or to 100 c.

13. Burn the filter and add the ashes to the precipitate and weigh; continue drying and weighing until the weight is constant, and the formula is $Fe_2\ O_3$.

14. To calculate the percentage of iron, if 2 grammes of ore were taken, multiplying the weight by five gives the percentage of oxide of iron.

15. If $2\frac{1}{2}$ grammes of ore were taken, then multiply the weight by 4 to find the percentage of oxide of iron.

16. These weights of the oxides of iron multiplied by 70 gives the percentage of metallic iron in the ore.

VOLUMETRIC DETERMINATION OF IRON BY POTASSIUM PERMANGANATE.

1. Dissolve five grammes of pure crystallized potassium permanganate in distilled water by aid of heat, dilute to one litre and preserve in a stoppered bottle; keep it in a dark place. The solution, if carefully kept, does not alter, but it is best to titrate it occasionally.

2. Weigh off accurately 1 gramme of thin, soft, clean, iron wire. Transfer it to a $\frac{1}{4}$ litre flask containing 100 c.c. of dilute sulphuric acid (one to five).

3. Many chemists use a valve-flask for this purpose to prevent the oxidization of the iron during solution.

4. But I prefer to dissolve without going to the trouble of preparing a valve-flask, and afterwards reducing the small amount of iron which may have been oxidized, by the addition of some granulated zinc.

5. This reduction takes but a few minutes. When the iron is all reduced, which may be determinied by removing a drop of the solution on a glass rod, and testing it on a porcelain plate with a drop of ammonium-sulpho-cyanate solution (if the iron is all reduced to the proto-state the drop will remain colorless, while if any ferric oxide is present the drop will turn red, the depth of color depending on the amount of ferric iron present.)

6. The contents of the flask are diluted by the addition of cold, distilled water, and the solution decanted off from the zinc to a large beaker, or an ordinary glass battery jar, which is less liable to breakage in stirring with the glass rod.

8. The flask and zinc are well washed, the washings being transferred to the jar and added to 10 c.c. of sulphuric acid.

8. The solution is then diluted up to the 250 c.c. mark

and allowed to stand and settle so that the particles of carbon present may deposit.

9. Now take out with a pipette 50 c.c. of the clear and nearly colorless fluid (containing one-fifth of the iron weighed off) transfer to a 400 c.c. beaker, and dilute till the beaker is half full. It is always best to use the same jar and always fill to the same point so as to have the same bulk of solution.

10. Place the beaker on a sheet of white paper, or better, on a sheet of glass, with a white paper underneath.

11. Fill a Gay Lussac burette, divided into 1-10 c.c. up to zero, with a solution of potassium permanganate, of which take care to have at hand well mixed.

Now add the permanganate to the previous solution, stirring all the while with a glass rod. At first the red drops disappear very rapidly, then more slowly.

12. The fluid which, at first, was nearly colorless, gradually acquires a yellow tint. From the instant the red drops begin to disappear more slowly, add the permanganate with more caution, and in single drops, until the last drop imparts to the fluid an unmistakably reddish color which remains on stirring.

A little practice will enable one to easily hit the right point. Now read off and mark the number of c.c. used. Use a float in your burette, and the reading off must be exact, the whole error not being more than 1-10 c.c.

13. The amount of permanganate solution used should be about 20 c.c. Repeat the experiment with another 50 c.c. of the iron solution. The difference between the permanganate used in the cases should not be more than 1 c.c. If it is, make one more erperiment, and when the result is sufficiently near take the mean of the three as the standard.

14. Now calculate what quantity of iron is represented by 100 c.c. of the permanganate. To this end, first divide

the iron weighed off by 5, and then multiply by 996, since soft iron wire contains, on an average, .4 per cent of carbon, and this gives the quantity of pure iron contained in the 50 c.c. of the solution.

15. Suppose we took 1.050 gms. iron wire and used a mean of 21.3 c.c permanganate; 1.050_{5}=.210; .210 times 996=.20916 and then by rule of three:—

.213: 20.916:: 100:? which equals .98,197. Therefore, 100 c.c. permanganate =.98197 pure iron. This experiment can be done with 200 grams of iron wire and the whole of the solution titrated, if desired.

16. To assay the iron ore grind it to a fine pulp, and weigh off one gramme accurately; dissolve it in sulphuric acid by heat; filter and wash. Make up the same bulk and titrate the solution the same as the standardizing solution and calculate accordingly.

If there is a deficiency of free acid in either of the above named solutions, the fluid may become a dark brown color, turning turbil and depositing a brown p.p., as if the permanganate were added too quickly; stirring too slowly may cause the same result. In such a case it is best to reject the whole thing and start anew.

If the fluid reddened by the last drop of the solution of permanganate added loses its color again after a time, it need create no surprise or uneasiness, for a dilute solution of free permanganate cannot keep long without decomposing; it does not affect the result. Do not add anew, thinking you have not finished the work.

EXERCISES.

1. For what purpose is iron mostly used in smelting ores?
2. What is first determined in an assay of iron ore?
3. What is the second determination?

4. What amount of ore is generally sufficient to make an assay?

5. What would you first oxidize the ore with?

6. After evaporating to dryness, how would you treat it?

7. What does the insoluble residue consist of, and how would you treat it?

8. Why would you add ammonia?

9. Why add sulphide of ammonia?

10. What effect does the boiling have on the precipitate?

11. If the ore contains alumina would it precipitate, and where would it be?

12. How would you separate alumina from iron?

13. How much of a heat would you give it before weighing?

14. If two grammes of the ore were used, how would the percentage of oxide of iron be calculated?

15. If $2\frac{1}{2}$ grammes were used, how calculate?

16. How would you calculate the metallic iron?

EXERCISES.

1. How would you prepare potassium permanganate solution for volumetric assay of iron?

2. How is it standardized?

3. Is a valve-flask necessary?

4. (a) In what state is the iron when dissolved in sulphuric acid?

(b). What would you add to prevent its oxidizing?

5. How is it tested to ascertain whether it is in a ferric or ferrous oxide?

6. How is the solution tested before placing it into a beaker for titration?

7. Would you wash the zinc and flask?

8. To what degree is it diluted?

9. What amount is taken for titration?

10. How is the beaker and jar arranged?

11. Explain further the method of standardizing with the burette.

12. How does the coloration take place?

13. How many experiments would you make before taking the mean?

14. Make the calculation of the strength of the permanganate solution.

15. Suppose you take 50 c.c. of the solution and the mean was 21.3 c.c., make the calculation of the strength of the solution.

CHROMIUM.

There are several methods for the determination of chromic oxide ($Cr_2 O_3$) in an ore. Mitchell's method by precipitation with nitrate of mercury is very good. But the following from Furman is as good as any:

1. "Chromium is always determined as chromic oxide ($Cr_2 O_3$), dark-green in color.

2. "The only determinations of chromium which the metallurgical chemist will be called upon to make are in iron ores (especially chromic iron ore, known as chromite, or magnetite, which sometimes contain chromium), pig-iron and steel.

3. "ORES.—Fuse from 1.0 to 2.0 grammes of ore with 5 to 10 grammes of mixed carbonates of sodium and potassium and 1 gramme of sodium nitrate. Dissolve the fused mass in water and hydrochloric acid in slight excess, evaporate to dryness, and determine the silica in the usual way.

4. "To the filtrate from the silica add sodium carbonate until it is thoroughly alkaline, and then, without filtering out the precipitate, bromine water until the solution is deeply colored, stirring continually.

5. "Now add 3 c. c. of pure bromide and heat for one

hour, with frequent stirring, keeping the solution alkaline and gradually increasing the heat until it boils.

Allow to boil for one hour, when the chromic oxides should all be oxidized to chromic acid.

7. "Now filter (precipitate A) and wash thoroughly with hot water, washing first by decantation and then on the filter until the filtrate runs through colorless. Should the ore contain a large amount of chronium, in order to insure its complete separation, wash the precipitate on the filter back into the beaker with the wash-bottle, bring the bulk of the solution up to about 100 c. c. with water, add 2 c. c. of bromine, and proceed as before, filtering through the same filter.

8. "The filtrate will now contain all of the chromium as alkaline chromate, and probably some of the maganese.

9. "The precipitate will contain all of the other constituents of the ore. Partially neutralize the filtrate with nitric acid, add from 1 to 3 grammes of ammonium nitrate, and evaporate until no odor of ammonia is perceptible.

10. "Dilute with water, and should a precipitate form (precipitate B, probably $Mn\ O_2$, Si_2, $Al_2\ O_3$, and $Ti\ O_2$), filter, and wash with warm water.

11. "Acidify the filtrate with hydrochloric acid and saturate with sulphuretted hydrogen to reduce the chromic acid to sesquioxide. Filted out the precipitated sulphur and wash.

12. "In the filtrate precipitate the chromic hydroxide with ammonia, filter, wash, dry, ignite, and weigh the chromic oxide ($Cr_2\ O_3$). To obtain the weight of the chromium multiply the weight of the precipitate by 0.68619.

"Pig-iron, Steel, etc.—Dissolve the alloy in nitric and hydrochloric acids, evaporate to dryness, dry and ignite the insoluble residue. Fuse the insoluble residue with mixed carbonates and proceed as above."

DETERMINATION OF MAGANESE.

The best method and the one most used by western smelters is Volhard's Volumetric process.

1. Dissolve one gramme of the finely pulverized ore in 2c. c. of hydrochloric acid, 4 c. c. of nitric acid, and 6 c. c. of dilute sulphuric acid, in a flask or casserole the same as for iron, and evaporate to copious fumes of sulphuric anhydride.

2. Transfer the contents of the flask or casserole to a graduated 500 c. c. flask; wash into the flask with boiling water.

3. Then add an emulsion of zinc oxide to the contents of the flask until the acid is neutralized and the iron is all precipitated as sesquioxide; violent shaking of the contents of the flask greatly facilitates the precipitation of the iron.

4. After the precipitation is complete the oxide of zinc should be slightly in excess. The contents of the flask are then diluted with distilled water to the holding mark and after thorough shaking allowed to settle.

5. After the oxide has settled so that the liquid is comparatively clear, 100 c. c. or an equivalent part is drawn off by means of a pipette with distilled water, into the flask.

6. The contents of the small flask are then ready for titration with a standard solution of permanganate of potassium. The titration is performed as follows: The permanganate solution is dropped into the liquid in the flask from a burette, the contents of the flask being shaken after each addition of the permanganate solution, in order to facilitate the settling of the precipitated maganese dioxide.

From the amount of the precipitate and the rapidity with which the precipitate is formed after each addition of permanganate solution, the operator, after a little practice, will

be able to determine in what quantities it is safe to add the permanganate solution.

7. The addition of permanganate should be continued until a faint pink color appears about the edge of the liquid after shaking, when held against a white background.

8. The precipitation of the manganese is then complete, although it is safest, especially if the precipitation has occupied some time, to bring the contents of the flask again to boil and notice, after allowing the precipitate to settle, if the pink tint remains.

9. If the color should have disappeared, another drop of permanganate is added, the flask shaken, and the precipitate allowed to settle. If the color is permanent after settling the titration is complete.

10. The same solution of permanganate of potassium used for the determination of iron may be used for this determination.

11. In order to determine how much manganese one cubic centimetre of the permanganate solution is equal to, it is only necessary to multiply its volume for iron by 0.2946 to obtain its value for manganese; hence if the c. c. of the permanganate solution was equal to 0.010 gramme of iron, it would be equal to 0.002946 gramme of manganese. The reaction which takes place is as follows:

$$3\,Mn\,O \times Mn_2\,O_7 = 5 Mn\,O_2.$$

12. Some chemists prefer to filter off the precipitated oxides before diluting to 500 c.c., but this is unnecessary, as the precipitate occupies a small bulk although in its flacculent state its bulk appears to be large, that it may be disregarded. Besides, the precipitate is difficult to wash, and the filtrate will give too low results.

13. The zinc used must be pure and contain no manganese.

EXERCISES.

1. Is chromium determined as an oxide or sulphide?
2. With what is chromium combined in the ore?
3. How will you treat the ore and determine the silica?
4. How is the filtrate then treated?
5. What is the object of adding bromine?
6. Why is the filtrate boiled?
7. How is the precipitate A to be treated?
8. In what form is the chromium now on the filter?
9. What else may the precipitate contain?
10. How is the filtrate treated to obtain precipitate B?
11. And how will you treat this filtrate?
12. After washing, drying, and weighing, how will you determine the chromium?
13. How would you determine the chromium in pig-iron or steel?

EXERCISES.

1. What amount of the manganese ore would you take for the assay and what and how much acids are used?
2. When transferred to a 500 c.c. flask, how is it treated?
3. For what purpose would you add an emulsion of zinc oxide?
4. What would you do after the precipitation is completed?
5. After the liquid has settled clear what amount is taken for the assay?
6. How would you titrate it? Explain the process in full.
7. What is the point of completion of the titration?
8. Should it proceed slowly or quickly?

9. How would you terminate the titration?

10. What solution of permanganate may be used?

11. How is the calculation for the percentage of manganese made?

12. Is it necessary to first filter the solution from the ore? If not, why not?

13. Why should pure oxide of zinc be used?

ASSAY OF ZINC ORES.

Zinc, like other metals, has several methods of determination, and each method has its advocates; but the following seems to be the simplest of them all and can be applied to any and every kind of ore indiscriminately:

1. Take from 1 to 10 grammes, according to richness, treat with a mixture of sulphuric, nitric, and hydrochloric acids, and decompose in a porcelain dish on a sand bath; add some water and then excess of ammonia and also some ammonia carbonate. Keep warm for some time.

2. Filter, wash with ammonia water until the drippings give no p.p., dark or white with ammonium sulphide. The impurities are now mostly left on the filter.

3. To the clear filtrate and washings add ammonia sulphide (which should be free from carbonates) as long as it precipitates and until the liquid smells of it. Stir, settle, filter, keeping the filter nearly full, and covered as much as possible.

4. Wash with water containing ammonium sulphide, keeping the filter covered as before. When finally draining, add a few drops of ammonium sulphide to prevent oxidation of p.p. and consequent loss of zinc.

5. If the precipitate consists only of zinc sulphide it will be white, otherwise, as in presence of silver, copper, nickel, or cobalt, it will be mixed with black, white, or yellow p.p., showing that cadmium is present or that some arsenic remained after the first treatment with ammonia, which might have been removed by addition of magnesia mixture. But in this assay these substances may be disregarded. Manganese sulphide being of a pale flesh color is not conspicuous in presence of

zinc sulphide. However, if present, it may be removed by washing the p.p. with acetic acid, and afterwards displacing that by water.

6. Now place a clean beaker under the filter, and, not entirely uncovering the latter, pour on the edge all around some warm dilute hydrochloric acid; this will dissolve the zinc sulphide, leaving copper, nickel, cobalt, cadmium, and arsenic sulphide unacted on, on the filter.

7. When all the zinc is dissolved, again place a clean beaker under and pour the solution so far got,again on the same filter.

8. When the liquid has passed, pour some more of the dilute acid on the edges and afterwards wash with water. The zinc is now in the filtrate.

9. If there should be much sulphide of copper or other substances left on the filter it will be best to take the filter and contents, place it in a beaker, and then digest with warm dilute hydrochloric acid and then filter and wash, and add the filtrate and washings to the zinc filtrate above.

10. We have now arrived at a point where the zinc in the solution can be determined either as an oxide by precipitating it with a solution of bicarbonate of soda or volumetrically.

11. To precipitate as zinc carbonate, heat the solution to boiling, and add a crystal or two of potassium chlorate.

12. Continue boiling, with the addition of small quantities of the chlorate until any turbidity which may appear, clears up and a smell of chlorine is perceptible; (it may be necessary to add a few drops of hydrochloric acid, if not enough is present.)

13. To the clear solution in a large covered beaker, add solution of sodium carbonate as long as it precipitates; heat

to boiling for 20 minutes, and collect the precipitate on a filter.

14. Wash until the drips no longer show a precipitate with nitrate of silver, or is neutral to test paper; dry, transfer the p.p. to a porcelain dish, burn the filter and add the ash; calcine at a red heat as long as the weight is inconstant, cooling and weighing from time to time. The zinc is now the white oxide, yellow when hot, white when cold. Now calculate the percentage of zinc in the ore from the amount of ore used.

16. Multiply the weight of the oxide by the coefficient 80.26, and you have given the percentage of metallic zinc in the ore.

In large smelting companies where the determination of zinc is often required the volumetrical method has the advantage of being rapid, and is accurate enough for all practical work.

The method here introduced is due to Fahlberg and requires a standard solution of potassium ferrocyanide.

17. "A solution of which one cubic centimetre is equal to 0.010 gramme of zinc is the solution generally preferred by most chemists using this method. To prepare such a solution 45 grammes of pure potassium ferrocyanide (free from potassium ferricyanide) are dissolved in one litre of water and kept in a tightly stoppered green-glass bottle.

18. "The solution will keep for some time without alteration, provided the bottle is well stoppered, and need not be tested more frequently than once every two or three weeks. It is best to make up the solution at least one day before using.

19. "To standardize the solution, dissolve two portions of about 0.250 grammes each of pure zinc oxide (the zinc oxide should previously be ignited to convert any carbonate of zinc into oxide, and kept in a stoppered bottle so that it

may not absorb carbonic acid or water from the air) in 5 c.c. of pure hydrochloric acid, and add 50 c.c. of water in a beaker of about 300 capacity.

20. "In order to have the same conditions present as near as possible as in the actual analysis, it is well to add ammonia in slight excess and then neutralize with hydrochloric acid, using a small piece of litmus paper as an indicator.

21. "When the solution has been brought to the point where it is just slightly acid, add an excess of 10 c.c. of pure strong hydrochloric acid, and dilute to 250 c.c. with cold distilled water.

22. "The solution is now ready for titration with the ferrocyanide solution, which may be run in from a burette, rapidly at first, stirring from time to time.

23. "If 0.2493 gramme of pure oxide of zinc were weighed out, it would require practically 20 c.c. of the ferrocyanide solution to precipitate the zinc, provided the solution were normal; hence in this case about 18 c.c. may be run in before testing.

24. "In order to test, the solution is thoroughly stirred with a glass rod, and a drop removed and added to a drop of a solution of pure uranium acetate on a porcelain plate.

25. "The uranium-acetate solution is prepared by dissolving sufficient uranium acetate in water to give a pretty strong solution, and clarified by adding a few drops of acetic acid. This solution should be kept in a small stoppered bottle in a dark place, as it is decomposed by the action of sunlight. As long as there is not an excess of ferrocyanide in the solution the drop of uranium acetate will retain its yellow color; as soon as the ferrocyanide is in slight excess it will turn a light brown, the shade being darker according to the amount of ferrocyanide in excess. The titration should be proceeded with, testing after the

addition of each drop of ferrocyanide towards the last of the operation, and stirring well before testing, until a slight brownish tint is produced on the drop of uranium acetate. The amount of ferrocyanide used is then noted, and the value of one cubic centimetre calculated. The duplicates should not differ by more than one-tenth of a cubic centimetre.

26. "The precautions to be observed are: To have about the same bulk of solution in all subsequent titrations; to have the same amount of hydrochloric acid present; to have the standard solution at about the same temperature, and to have the zinc solution comparatively cool. If too large an excess of acid is present, or if the zinc solution is too warm, a decomposition will ensue, resulting in the liberation of chlorine. This may be seen by the solution turning yellow or yellowish-green. The precipitate should always be white, and the solution colorless or nearly so."

EXERCISES.

1. What amount of zinc ore would you take for an assay, and with what acids would you treat it?
2. How proceed after digesting it with acids?
3. Through what process would you put the filtrate?
4. What should be done while it is on the filter?
5. What is the appearance if it contains silver, copper, arsenic, or cadmium?
6. What is the next step in the assay?
7. What is left on the filter when all the zinc is redissolved?
8. Where is the zinc when the liquid has all passed through the filter?
9. How is the substance left on the filter treated?
10. At what point has the assay now arrived?

11. How is the filtrate treated to precipitate as zinc carbonate?

12. For what purpose is chlorate of potash now added?

13. Why would a solution of sodium carbonate be added?

14. How would you treat the precipitate on the filter?

15. In what form is the zinc at this stage? What is its appearance when hot? When cold?

16. How is the amount of metallic zinc determined from the oxide?

17. How is the standard solution of potassium ferrocyanide prepared?

18. How must it be kept?

19. How is this solution standardized?

20. What is necessary to have the same conditions in the analysis?

21. When the solution is brought to the point where it is just slightly acid what is added, and to what is it diluted?

22. What is the next step?

23. If 0.2493 of a gramme of pure zinc were weighed out, how many c.c. of the ferrocyanide solution would it take to precipitate the zinc?

24. How is it tested?

25. How is the uranium acetate prepared?

26. What are the precautions in this case?

ASSAY OF NICKEL AND COBALT ORES.

The analysis of nickel and cobalt ores has been considered one of the most tedious of any that falls to the lot of the assayer, owing to the separation of the two metals which are always associated together. But of late years the process has been somewhat simplified.

I have examined the various methods by different authors and find Aaron s to be the most satisfactory of all. By the use of his potassium xanthate he is enabled to throw down the cobalt xanthate first. I have made several analyses of nickel ore by this meth and find it less complicated than any other which I have used.

In order to make this assay it is necessary to prepare a solution of potassium xanthate which Mr. Aaron uses for the assay of copper by standardizing it the same as the cyanide of potassium solution; also the carbonate of zinc solution.

1. "Preparation of the Potassium Xanthate Solution. Dissolve two ounces (troy) of caustic potassa in about a quarter pint of 95 per cent alcohol in a stoppered bottle; add carbon disulphide, little by little, as long as a curd is produced, a hissing noise heard, and a partial vacuum is formed in the bottle, as evinced by the stopper resisting extraction. Shake the bottle occasionally. When the above effects cease, and a further addition of the disulphide causes expansion, which may expel the stopper, while its odor is no longer neutralized but becomes disagreeably perceptible, and a yellowish fluid appears which partly liquifies the previously almost solidified contents of the bottle, pour the whole into a dish and leave it to spontaneous evaporation in a dark, cool place for twelve hours or more, the dish will then contain a plastic mass; dissolve this in six pints of cold, pure water. Let the solution stand a short time to

deposit any excess of disulphide, and then bottle it in common beer bottles ("black bottles"), which keep in a dark, cool place.

"About 50 c.c. of the solution thus made will precipitate 0.5 of a gramme of copper; it may be diluted, if so preferred for very close work, so that it will require 100 or 200 c.c. for that quantity of copper. If the alcohol is not almost saturated with caustic potassa, the curdy mass spoken of may not appear until evaporation has taken place. The compound may be made in an open dish, the carbon disulphide being dropped into the alcoholic solution of potassa until that no longer reacts alkaline. The crystals of potassium xanthate are white; they may be washed with ether, and may be preserved indefinitely, and dissolved in water or in alcohol for use. Caustic soda may be used in place of potassa; the sodium xanthate forms orange-colored crystals. " "

"To Make the Zinc Carbonate, or rather hydro-carbonate, dissolve zinc sulphate in water, and filter it; also dissolve sodium or potassium carbonate in water. Filter the latter into the former until nearly but not quite all the zinc is thrown down; collect the p.p. on a filter and wash it. The filtrate should still give a p.p. on addition of the soda solution, in order to guard against an excess of soda which would be difficult to wash out of the zinc carbonate. Keep the carbonate moist in a wide-mouthed jar or bottle. Probably zinc oxide would answer as well, and would be more convenient, because it would not cause effervesence.

2. To make the assay of nickel and cobalt the ore may contain besides these metals, iron, manganese, zinc, copper, gold, silver, lead, bismuth, antimony, arsenic, calcium, barium, strontium, aluminum, magnesium, silica, and sulphur.

Should it also contain mercury, telurium, or selenium, these are easily expelled by roasting the weighed assay before proceeding further. "

3. Powder the ore very finely; take one to two and one-half grammes according to the richness of the ore.

4. Digest in plenty of nitrohydrochloric acid, the nitric in excess. Let all sulphur be dissolved, or remove the drops from the sufficiently cooled liquid, picking them out and rinsing them in water which falls into the solution.

,5. Add a little sulphuric acid, unless the ore contains a good deal of sulphur or copper or iron pyrites; evaporate nearly to dryness; cool, dilute, filter, and wash with hot water until the drippings give a dark p.p. with ammonium sulphide, by testing a drop of it on white porcelain.

7. "If the volume of liquid is now conveniently large, reduce it by evaporation.

8. "Add solution of caustic potassa or soda very carefully, not producing any distinct p.p., although in many cases a slight turbidity, but the liquid must remain slightly acid to test paper.

"If too much alkali be added, it must be counteracted by a drop or two of hydrochloric acid; it is better to use no alkali than too much.

10. "Now add moist precipitated zinc carbonate; stir, and continue adding the carbonate until a considerable excess of it remains unchanged in the liquid, which may be slightly warmed.

11. "If the assay contained no copper, test a minute drop on white porcelain, with a drop of solution of potassium sulphocyanate; when this gives no red or pink tinge, the iron is all down.

12. "If copper is present, test for that, in the same way, with potassium ferrocyanide, which will give a brownish red color as long as any copper remains in solution.

13. "As the iron goes down first, it is not necessary to test for that when copper is present; when the copper is all, or nearly all down, a bluish or greenish p.p. may be pro-

duced by this test, which must not be mistaken for the blue which the persalt of iron would produce; it is caused by cobalt or manganese.

14. "When the copper is all down, filter, and wash with hot water as long as the drips give a p.p. with solution of potassium xanthate. (Return these tests to the filtrate.)

15. "For a final test of the washings, place a drop on porcelain and add a drop of ammonium sulphide; it should not blacken.

16. "Now warm the liquid to about blood heat, or a little higher, and add solution of potassium xanthate, at intervals, as long as it is seen to produce a yellow or a greenish p.p. Keep the liquid warm, and let it stand some time, stirring occasionally, until it clears tolerably. Try a little more xanthate; it will probably make a white p.p. of zinc xanthate, which, however, either changes its color or disappears, being either converted to nickel or cobalt xanthate, or dissolved. At last, filter a little of the solution on a filter which has been exactly balanced with another on a fine balance. Test the filtered liquid with potassium xanthate; if any yellow or green p.p. forms, return the test to the main solution, and add more xanthate to that, but avoid a great excess.

17. "When no more p.p. forms, or only a white one which dissolves, make a final test with a drop of ammonium sulphide; it should give no black p.p. although a white one of zinc, perhaps tinged by pinkish manganese sulphide.

18. "Collect the p.p. after letting it settle, on the same filter that was used in testing; any p.p. which may adhere to the side of the beaker must be removed by the aid of hot water and a rubber-tipped glass rod; a short piece of pure rubber tube on the end of the rod will answer. Wash several times with rather hot water.

19. "Place a clean beaker under the filter, and leach

the p.p. with slightly diluted ammonia until that passes colorless, and a drop of it gives no p.p. with a drop of acetic acid (or very dilute sulphuric) enough to destroy the smell of the ammonia. Add the drop to the filtrate if it gives a p.p.

20. "Remove the beaker containing the ammoniacal solution of nickel xanthate, and wash the cobalt xanthate on the filter with hot water containing a little ammonia, until the filter is clean and the p.p. separates well from it under the jet.

21. "Dry the cobalt xanthate, still on the filter, and the counterpoise filter with it, on the waterbath; cool and weigh it, on the filter, putting the counterpoise filter on the weight pan; return both to the water bath for ten minutes; cool and weigh again, and so until it weighs twice alike.

22. "The cobalt xanthate should be of a dark pure but not brilliant green color; if mixed with orange yellow, it contains a considerable proportion of copper; when calcined, it should be black, not green, which indicates the presence of zinc, and if it gives a blue solution with ammonia, copper is present; the copper may be removed thus: Redissolve the calcined p.p. and the burned filter, in aqua regia; dry with addition of hydrochloric or sulphuric acid; take up with water and a little of the same acid; digest warm with a piece of zinc, keeping the liquid distinctly acid so that bubbles rise from the zinc; the copper will be precipitated; remove the zinc and copper, nearly neutralize the liquid by potassa, reprecipitate the cobalt by potassium xanthate, wash, dry, and weigh.

23. "To the ammoniacal solution of nickel xanthate,

add very dilute sulphuric acid until the greater part of the nickel xanthate is reprecipitated, but the liquid still smells of ammonia; then add acetic acid until the liquid has a slight acid reaction; stir, to curdle the p.p.; let stand for some time, stirring occasionally. Add a little potassium xanthate, and, if it produces a p.p., add as much more as may be necessary but avoid great excess. Collect on a counterpoised filter, cleaning the beaker as with the cobalt; wash with hot water until the p.p. cleaves readily from the filter under the jet; dry on the water-bath, cool, weigh, and so on until it weighs twice alike.

24. "Each of the xanthates contains 19.6 per cent of metal, or, the weight multiplied .196 is the weight of the nickel or cobalt. The filtrations may be greatly facilitated by connecting a foot of rubber tubing to the beak of the funnel and letting it hang downward, the end in the receiving vessel. This should not be done while leaching with ammonia.

> "In certain circumstances, believed to be the presence of arsenic in the solution, the precipitation of copper by zinc carbonate is not quite complete; if, however, there is sufficient iron present, the difficulty no longer exists; hence, if a little copper should remain in solution, notwithstanding an excess of zinc carbonate, add a little iron per-chloride, as nearly neutral as may be, and then more zinc carbonate if necessary. If the ore is known to contain arsenic, with but little iron, while copper is also present, it may save trouble to add a little metallic iron to the assay in the first instance. All iron in the solution must be in the form of a persalt, and it will be so if enough of nitric acid be used in making the

solution. In the treatment with zinc carbonate the liquid may be slightly warmed, not highly heated, or nickel and cobalt will also come down.

"The potassium xanthate made, as directed for the copper assay, with alcohol of 95 per cent or thereabout, is a little alkaline, and becomes more so by keeping; in this state it is not fit for this assay.

"Before using it, test it with faintly reddened litmus paper; if it blues that, add some very dilute sulphuric or hydrochloric acid, not strong enough to cause turbidity, or, if it does, warm the liquid until clear.

RESUME OF OPERATIONS.

1. "Dissolve; dry; take up; filter.
2. Treat with zinc carbonate; filter.
3. Precipitate with potassium xanthate; filter.
4. Leach with ammonia.
5. Dry and weigh cobalt xanthate.
6. Recover nickel xanthate by acid; filter, wash, dry, weigh.
7. Multiply weights by .196 for metal. If the greatest possible accuracy is required, see Fresenius' Quan An, or send the assay to an analytical chemist.

Sometimes a little of the cobalt is found mixed with the recovered nickel xanthate. To insure a perfect separation, collect the recovered nickel xanthate on the original filter, dissolve it again in ammonia and again recover it by acid as before, then collect it on a new counterpoise filter, dry and weigh. The whole of the cobalt will be on the first filter."

All the instructions must be followed out minutely, especially in preparing the zinc carbonate and xanthate solution, as well as the details of the operation, or no satisfactory results can be had.

EXERCISES.

1. How would you prepare a solution of potassium xanthate?
2. With what substances may nickel and cobalt be associated in the ores?
3. How is the ore prepared and what amount is taken for the assay?
4. What acid is used to digest it?
5. What is added if the sulphates are in the ore?

6. After cooling, diluting, filtering, and washing, what are the drippings tested with, and for what purpose?

7. What is done if the volume of liquid is too large?

8. What is added to the filtrate? Must it be alkaline or acid?

9. What is to be done if too much alkali is added?

10. What is next added to the liquid? For what purpose?

11. What is it now tested for? With what?

12. With what is the test for copper made?

13. Is it necessary to test it for iron when copper is present?

14. What is done when the copper is all down?

15. How are the washings tested? What are they tested with?

16. What is next done with it?

17. When no more precipitate forms, or only a white one, which dissolves, what would you test it with?

18. What is now done?

19. With what is the precipitate leached?

20. What does the filtrate now contain?

21. What is on the filter? How would you treat it?

22. What color is the cobalt xanthate?

23. What is now done with the nickel xanthate?

24. What per cent of the metal does each of the xanthates contain?

25. How is it determined?

MERCURY.

The distillation methods described by Fresnius, Mitchell, Rickette, Aaron, and others are good, especially if the percentage of mercury is large

1. For rich ores I frequently take as much as four ounces of the ore and mix it with five ounces of iron filings, and half an ounce of lime. (Iron filings in large excess are preferable, as it renders the mass more porous, and facilitates the distillation.

2. Put in a clean iron retort and place it in a furnace with the iron pipe leading out over a receiving dish of cold water, wrapped with a strong cloth which should be frequently saturated with cold water, or better still, keep a small stream of water running from a faucet over it.

3. Heat very gradually at first, with a red heat to finish. When the distillation is completed, which may be known by tapping the iron pipe with a hammer and no more mercury is seen to come over, shut off the fire or remove the retort from the furnace and let it stand until cold; disconnect the retort, cover, and pipe, and wash out completely into the receiving dish; pour off the greater part of the water.

4. Add a little potash solution to clean and facilitate the collection of mercury by one mass by rubbing it with the fingers; extract the remaining water with blotting paper, dry, and weigh, and calculate the percentage.

5. The assayer is frequently called upon to make an assay of very low grade ore running from two-tenths to one per cent of mercury.

For ores of this character I take the piece of combustion tubing about twelve or fourteen inches long annd closed at the left-hand end. Introduce a weighed quantity of the finely pulverized ore.

6. The ore introduced should be mixed with iron filings and lime. Shake the mixture down into the closed end. On top, near the right-hand end, place a very small plug of ignited asbestos. Lay the tube in a horizontal position and tap it so that an open passage will be left over the ore.

7. Into the right-hand end of the combustion tube introduce a spiral gold foil of known weight, also a rubber cork connected with a glass tube. This small tube should be about 18 inches in length, and should be bent up in the form of an L at the open or right-hand end. It can be kept cool by wrapping around it a cloth saturated with cold water. This second tube is to catch any mercury which might pass the gold foil.

After the apparatus is connected, heat the left-hand end of the tube containing the ore, but keep the right-hand end of the tube, containing the gold spiral, cool.

Should any mercury condense in the combustion tube, it can be driven forward by moving the flame of the burner towards the right.

> I find it a good plan to lay the combustion tube in a combustion furnace with a little charcoal around it, and then when the tube is heated it will keep hot and prevent the return of the mercury to the left-hand end of the tube.

8. After all the mercury is distilled, which will require from 15 to 30 minutes, remove the heat and allow the tube to cool. When cool, disconnect the apparatus, examine the small tube, and if it contains any mercury, wash it out with the wash-bottle, add to the gold spiral, and weigh.

The increase of the weight of the gold will represent the mercury. This process, well performed, gives excellent results, when the ore is as low as two-tenths of one per cent. A small amount of rich ore, one or two grains, may be as-

sayed in the same way. There are several methods of determining mercury in wet way, but they are extremely tedious, and far from accurate.

ASSAY OF ARSENIC.

The best method for the determination of arsenic is that devised by Dr. Richard Pearce, of Denver, Colorado. It is the most accurate and rapid method we have.

1. The finely powdered substance for analysis is mixed in a platinum crucible with from six to ten times its weight of a mixture of equal parts of sodium carbonate and potassium nitrate.

2. The mixture is then fused gradually until it flows smoothly. It is then cooled and extracted with water warmed in the crucible and filtered.

3. The filtrate contains the arsenic combined with alkalies.

4. Acidify with nitric acid and boil; cool; neutralize almost exactly by ammonia, so that previously reddened litmus paper shows alkali in half a minute. If not clear, filter.

5. Add a neutral solution of nitrate of silver in slight excess.

6. Stir to coagulate the precipitate which is of a brick-red color. Filter; wash the precipitate with cold water. Dry, scorify the precipitate with lead and cupel the button.

> Test the filtrate with silver nitrate, dilute nitric acid and ammonia to again neutralize in order to see that the precipitation is complete. The second neutralization is always necessary when the amount of arsenic is large, as nitric acid is set free in the reaction between the alkaline arsenite and silver nitrate according to the following: $3\ (Ag\ NO_3)$ -|- $Na\ H_2\ As\ O_4 = Ag_3\ As\ O_4$ -|- $Na\ No_3$ -|- 2 (HNO_3).

7. If the ore contains any chloride—silver chloride, etc., (which is seldom the case), or if the water or soda used

contained chlorides, then instead of at once scorifying the p. p. pour dilute nitric acid over it while on the filter to dissolve the silver arsenite and separate it from the silver chloride, which will remain on the filter.

8. To the liquid add enough of hydrochloric acid to precipitate all the silver on it as chloride.

9. Collect the chloride on a filter, wash with hot water, dry, and scorify with lead, adding a little soda.

10. The weight of the silver obtained multiplied by ..2315 gives the weight of arsenic in the assay.

In precipitating arsenic with silver nitrate, the best way, although it requires a long time, is to acidulate the alkaline solution with nitric acid; dilute largely if the substance contains sulphur, add a sufficient quantity of silver nitrate—which need not be neutral—then excess of ammonia to redissolve any p. p., and finally evaporate withoct boiling until the odor of ammonia is gone, when the silver arsenic will come down.

EXERCISES.

MERCURY.

1. How is cinnabar ore prepared for an assay?
2. If an iron retort were used how is it arranged?
4. How is the mercury cleaned and collected?
5. How would you assay a low-grade ore?
6. How is the apparatus arranged?
7. How is it charged?
8. How is the mercury collected and saved?

ARSENIC.

1. With what and how is arsenic ore prepared for an assay?

2. How is the mass treated after fusing?

3. Where is the arsenic after filtering?

4. How is the filtrate then treated?

5. What is now added? For what purpose?

6. How is the p. p. collected, and how is it treated?

Would you test the precipitate? Write the reaction which has taken place.

7. What is done if the ore contains any chloride?

8. What is done if further p. p. is found?

9. How is the silver button collected and treated, and the amount of arsenic in the ore estimated?

10. Why multiply by .2315?

ASSAY OF ANTIMONY.

1. Weigh out a suitable quantity of the ore and fuse it with 4 parts of cyanide of potassium (if this is not at hand equal parts of borax and carbonate of soda will do); place it in a small clay crucible and fuse it until it flows smoothly. Pour it into an assay mold, or cool it in the crucible, breaking the pot to extract the button.

2. Clean the button and place in a dilute solution of hydrochloric acid, as it will not bear the hammer.

3. If the ore contains no lead or other metals the button may be weighed at once as metallic antimony.

4. But if it contains lead or other metals, pulverize or flatten it with the hammer and boil it in diluted nitric acid.

5. This will leave nearly all the antimony in a white powder, which, when washed on the filter, dry and fuse again with cyanide of potassium. This will give you a button of pure antimony, unles tin be in the ore, which is not likely.

6. Second Method.—The ore can be fused with about six parts of equal quantities of sulphur and soda in a tightly covered crucible. When sufficiently fused and the greater part of the sulphur burned out, cool, and extract the button with hot water, which dissolves the antimony.

7. Filter; to the filtered solution add hydrochloric acid to acid reaction; collect the precipitate on a filter and wash into a beaker.

8. Then pour on the filter a solution of nitre, dry and burn the filter, adding the ashes to the precipitate.

9. Then treat the whole mass with nitric acid until all sulphur is oxidized. Evaporate nearly to dryness; cool; dilute with water and filter.

10. The antimony remains on the filter in a pure state,

which fuse with cyanide of potassium as before; extract button, clean, weigh, and calculate the percentage of metallic antimony.

ASSAY OF BISMUTH.

1. Bismuth ore may be assayed much the same as lead by mixing the finely powdered ore with equal parts of cyannide of potash and bicarbonate of soda.

2. If the ore contains any copper, add sulphur to keep the copper out of the button.

3. If the ore contains no sulphur or arsenic add one part of sulphur and a little charcoal with three nails to the dressing. The following is a good charge for an assay:

4.

Ore	1	Part.
Sulphur	1	"
Charcoal	$\frac{1}{4}$	"

Cover with salt and smelt in the crucible the same as lead, and calculate the percentage of bismuth.

5. Cupel the button for gold and silver. If much of either metal is in the button, deduct it from the weight of the button.

6. Lead and antimony, if present, will go into the button. If the ore is poor in bismuth add some litharge to the dressing to collect the bismuth, using 40 per cent of litharge for an ore containing 10 per cent of bismuth. In such a case make the following charge:

7.

Ore	1	Part.
Litharge	4-10	"
Sulphur	1	"
Charcoal	$\frac{1}{4}$	"

Cover with salt and add three nails.

8. If the ore is rich in copper and it comes down with the lead and bismuth, making it hard, flatten it out and boil in dilute nitric acid. It will dissolve the bismuth, lead, copper and silver.

9. If there is any tin or antimony in the ore it will be insoluble. Filter and add enough sulphuric acid to the fil-

trate to precipitate the lead; boil the acid down; cool; add water and boil. If there is any soluble matter let it settle; decant upon a filter; boil several times with water and a little sulphuric acid, decanting upon the filter, washing slightly.

10. To the filtrate add excess of ammonia carbonate and heat to boiling. Filter and wash with ammonia water until that passes colorless; dry on filter; smelt the p. p. with filter and all together with a little borax glass and potassium cyanide. Separate the button from the slag; weigh and calculate the percentage of bismuth.

EXERCISES FOR ANTIMONY.

1. How would you make a charge for antimony ore?
2. How may the button be cleaned?
3. What is done if the ore contains no lead or other metals?
4. How is it treated if it contains lead?
5. (a) How will it leave the antimony after boiling with nitric acid?

(b) What would you then do with it?

6. How is the ore treated by the second method of assay?
7. What is added to the filtered solution? For what purpose?
8. How may the filter and contents be treated?
9. What is done with the whole mass?
10. Where is the antimony after the second filtering?

BISMUTH.

1. (a) How can bismuth be assayed? (b) With what is it fluxed?

2. What is the manner of fluxing if it contains copper?

3. If no sulphur is in it, what is added?

4. What are the proportions of the charge?

5. If it contains either gold or silver, how are they separated?

6. What is the method of treating a low-grade ore?

7. In that case what is the charge?

8. (a) When the ore is rich in copper what is the appearance of the button? (b) How is the button treated, and what is the effect of dissolving it?

9. What is done if the ore contains tin?

10. How is it treated?

11. How would you treat the filtrate and calculate the percentage?

DETERMINATION OF SULPHUR.

This method for the determination of sulphur was first proposed by M. W. Iles, and, I believe, has been adopted by all the Western smelter and mining companies, although it is almost impossible for any two chemists to obtain results that will agree by this or any other method. Fresenius, who is the recognized authority, declares that this method is subject to error from 2 to 3 per cent, but it has not been improved upon.

1. C. H. Aaron recommends fusion of the powdered ore with nitre and alkaline carbonates, which may do for ordinary sulphurets, such as pyrites, etc.

2. For the determination of rich sulphur ore, especially that which is imported from Japan, it will not do, as the nitre and sulphur with any of the carbonates will form an explosive equal to gunpowder, and when fusion takes place an explosion will invariably occur.

3. The best decomposing agent is caustic potash alone, which has been prepared with alcohol. This comes in sticks.

4. Weigh out one to two and one-half grammes of the finely powdered ore, according to richness. Fuse eight to ten parts of the caustic potash first in a platinum dish, then partially cool and brush the ore on top of the partly fushed potash; heat from 5 to 20 minutes until it is completely decomposed, using a spirit lamp for this purpose, as coal gas often contains some sulphur compounds.

5. Remove the dish and allow it to cool; as soon as cold dissolve the mass out with warm water into a beaker, and when it is all transferred to the beaker,bring the contents to a boil, and filter through a ribbed filter paper.

6. Wash with boiling water until the washings come through free from sulphides or sulphates. Add 20 to 40 c.c. of bromine water to the filtrate and heat to about 90 degrees Centigrade, and then acidify with hydrochloric acid.

7. If the substance contains silica it will now be in solution and must be removed by evaporating to dryness, heating and dissolving with water and hydrochloric acid and filtering off the silica thus rendered insoluble.

8. To the filtrate from the silica, after boiling, add a solution of boiling barium chloride until all of the sulphur is precipitated as barium sulphate.

By heating the solution of barium chloride before adding it to the solution the barium sulphate is precipitated almost immediately.

9. This would not be the case if a cold solution of barium salt were used. After the addition of the barium chloride the solution is brought to a boil and then removed to a warm place and allowed to settle.

10. After settling, it is filtered and washed thoroughly with boiling water, and then with a few drops of dilute hydrochloric acid dropped around the edge of the filter, and again twice with hot water.

11. It should be washed until the washings no longer give a precipitate with silver nitrate solution.

12. The precipitate is now dried together with the filter paper, and when dry transferred to a platinum crucible and gently rolled with the fingers.

13. The crucible is placed on a sheet of glazed paper or a large watch glass, so that any particles which may fly over the sides of the crucible may be recovered.

14. After cleaning the paper it is rolled up and placed on the lid of a platinum crucible and burned by holding

the platinum over the uame of the burner. The ash of the filter-paper is then added to the contents of the crucible, and the whole ignited to redness over a blast lamp.

15. The crucible is then cooled and its contents should be found perfectly white. The precipitate is now transferred from the crucible to the watch glass pan of the balance and weighed.

16. The weight of the barium sulphate less the known weight of the filter-ash, multiplied by 0.13734, will be the weight of the sulphur present in the amount of ore or substance taken for assay.

When silica is not present the evaporation to dryness of the filtrate from the solution of the fusion may be dispensed with, thus saving much time. This method is universal in its application, but requires much time, and where great accuracy is required it should be done in duplicate.

The following method from Furman is frequently used in lead and copper smelting works for the determination of sulphur, and whilst it is not as accurate as the method previously described, it has the advantage of being rapid, and consequently would be used where time for an accurate determination is not available:

"Treat one gramme of ore in a flask (about 200 c.c. capacity) with three to four grammes of potassium chlorate and 7 c.c. of nitric acid, the acid being added as follows: About 3 c.c. at first, and then 1 c.c. from time to time. When all the acid has been added, heat to boiling on a sand-bath and evaporate off the excess of acid. All but about 2 c.c. of acid should be expelled. The potassium chlorate and nitric acid oxidize the sulphur in the ore, and in the case of a heavy sulphide more potassium chlorate may be necessary. The solution, after boiling, should show no undecomposed particles of sulphides and no globules of yellow sulphur, which will sometimes form if the oxidation

has been imperfect. Remove from the source of heat, dilute with about 50 c.c. of water, and add a saturated solution of sodium carbonate in excess. The sodium carbonate precipitates the lead, iron, etc., and the excess is added to decompose the sulphates of lead and calcium which may have formed during the solution. Boil for from 30 minutes to one hour, adding water from time to time to keep the bulk of the solution about the same. Filter through a fluted filter into a beaker, and wash until the washings no longer show the presence of sulphuric acid. Acidify the filtrate with hydrochloric acid, and boil to expel the carbonic acid. When the carbonic acid is all expelled the solution is ready for the precipitation of the sulphuric acid with barium-chloride solution, and the determination of the barium sulphate as before. If the ore contains barium sulphate it will remain undecomposed with the precipitate of mixed carbonates."

EXERCISES.

1. What is Aaron's method for the determination of sulphur?
2. In what way is Aaron's method defective?
3. What is the best decomposing agent for all ores?
4. What is the mode of procedure?
5. After fusion, how would you treat the contents of the crucible?
6. What is added to the filtrate after filtering and washing?
7. What is done if the substance contains silica?
8. After filtering off the silica, what is the next thing to do?
9. Why are the hot solutions necessary?
10. After settling and filtering, how is the precipitate on the filter treated?

11. How long is the washing in hot water continued?

12. What is next done with it?

13. How is it prepared for ignition?

14. What is done with the filter?

15. What is the appearance of the barium-chloride?

16. After weighing how would you determine the amount of sulphur, and why would you multiply by 0.13734?

17. In what cases can this method be shortened?

ASSAY OF PLATINUM.

1. Platinum and gold concentrates are separated from the black sand as much as possible and melted with an equal weight of pure silver and a little borax to clean. Place them in a small black lead crucible, pour the charge out on an iron plate and treat as an alloy the same as a gold bullion assay.

2. But it must be parted with sulphuric acid instead of nitric acid, and the cornet should be boiled in the concentrated acid for twenty minutes, when the acid is poured off and fresh added, boiling for ten minutes longer.

3. The resulting cornet is washed, dried, cleaned, and weighed.

4. The weight being gold and platinum, some small amount of silver invariably remains in the cornet.

5. So it is necessary to run a proof gold assay made up exactly as the regular assay and along with it. Whatever gain in weight (above the weight of the gold and platinum taken) the proof shows, must be deducted from the weight of the cornet obtained in the regular assay.

6. Alloys Containing Iridium and Osmium.—Alloys containing these rare metals will be found with the gold and platinum cornet, and may be separated by dissolving the cornet in aqua regia, evaporating until the nitric acid is expelled, diluting with distilled water, and filtering off the iridium and osmium which may be dried and weighed.

7. We now have a solution containing the gold and platinum dissolved with the aqua regia and nitric acid expelled.

8. To separate them we first determine the platinum by mixing the solution in a beaker with potassa until the

greater part of the acid is neutralized; add potassium chloride slightly in excess, and then add a pretty large quantity of strong alcohol; if the solution of platinum is very dilute, concentrate it by evaporation before adding alcohol.

9. After twenty-four hours collect the precipitate on a rather small filter, wash with alcohol at 80 per cent. Dry thoroughly at 100° C. and transfer to a porcelain crucible; dissolve the portion which adheres to the filter, and, evaporating the solution in the crucible, ignite with hydrogen to convert the compound into metallic platinum and potassium chloride.

10. Reduction is best effected if the heat is very gradually applied and does not quite fuse the potassium chloride.

11. After reduction, wash out the potassium chloride, ignite and weigh the platinum.

12. The filtrate and washings from the platinum is now evaporated to a small bulk and hydrochloric acid added, if it does not already contain some of that acid in the first state, and add a clear solution of ferrous sulphate in excess; heat gently for a few hours until the precipitated fine gold powder has completely subsided; filter, wash, dry and ignite. Cool and weigh metallic gold. These results are accurate.

EXERCISES.

1. How would you fuse platinum and gold sand?
2. What would you boil the cornet in to part it?
3. How is the cornet treated after parting?
4. Of what is it composed?
5. Would you run another assay?
6. How are the iridium and osmium obtained?
7. Where are the gold and platinum now?
8. How is the platinum now separated?

9. What is the platinum washed with? For what purpose?

10. How is it reduced?

11. How are the filtrate and washings now treated to obtain the gold?

12. How, and with what is the gold precipitated?

COAL ANALYSIS.

1. An approximate analysis of coal may be made by determining the amount of moisture, volatile matter, coke, ash, and sulphur; but if the actual amount of carbon, hydrogen, and nitrogen is required, an elementary analysis must be made which involves much time, labor, and apparatus, but for ordinary purposes an approximate analysis will suffice.

2. To Determine the Moisture.—Weigh out 2 or 2½ grammes of the finely powdered coal and place it in a dish in a dry oven with thermometer attached. Dry for one hour at 105 to 110 degrees C. and the loss is moisture. With the quantity of coal taken the loss of weight appears greatest at the end of this time, but upon a further heating it actually increases in weight owing to the oxidation of the pyrites.

3. Determination of Volatile Matter.—About 2 to 2½ grammes of the powdered coal are heated from 4 to 5 minutes over a Bunson flame in a platinum crucible with the cover on and then immediately, without cooling, for four minutes in a hot flame until the crucible and contents are at a red heat and all gas has escaped. The loss is set down as volatile matter and moisture. The volatile matter carried off one-half of the sulphur. Subtract moisture and we have the weight of each; the residue gives coke and ash which are now separate.

4. Determination of the Ash.—Weigh out one or two grammes of the finely powdered coal, place it on the platinum crucible, cover on a wire gause over a Bunsen's burner; heat gently at first until the moisture and volatile matter has passed off, then keep at a red heat until all the

carbon has burned out, leaving the ash on the cover. The weight of the ash subtracted from the weight of the coke gives fixed carbon and one-half sulphur.

5. Determination of Sulphur.—Sulphur in coal exists in two forms, as pyrites and as calcium sulphate.

6. The total amount of sulphur may be determined by heating two grammes of the powdered coal in six times its weight of pure sodium carbonate or caustic potash in a platinum dish, and treated the same as the assay of sulphur on page —, and weighed as barium sulphate, and then deducting one-half of its weight from the volatile matter and the other half from the fixed carbon.

7. The means of tabulating results is best illustrated by the following example:

Moisture	3.2
Volatile matter $\times$ $\frac{1}{2}$ sulphur	26.5
Fixed carbon $\times$ $\frac{1}{2}$ sulphur	60.3
Ash, including phosphorus	10.0
Sulphur	0.7

When the sulphur is determined and one-half deducted from the volatile matter and the other half from the fixed carbon, the results will stand as follows:

	Per Ct.
Moisture	3.20
Volatile matter	26.15
Fixed carbon	59.95
Ash, including phosphorus	10.00
Sulphur	.70
	100.00

100 parts of the raw coal gave of coke 69.95

The coke was composed of

	Pr Ct.
Carbon	85.69
Ash	14.31
	100.00 including sulphur .0070 per cent. including phosphorus—trace.

It is sometimes necessary to calculate the quantity of heat evolved during combustion of a given amount of fuel.

8. The products of combustion are of two sorts:

First—The physical products, the heat and light for which the combustion is generally produced.

Second—The mechanical products which are to be conveyed away. The heat of combustion is measured in heat units, a heat unit being the quantity of heat required to raise one gramme of water from 0° to 1°.

9. Thus the heat of combustion of carbon when burnt in oxygen gas in the ordinary physical state, is called the calorific power of the combustible, and it has been found that burning one gramme of wood charcoal in oxygen would heat 8,080 grammes of water from 0° to 1°. Knowing, therefore, the quantity of carbon in a given fuel it is easy to calculate its value for heating purposes by multiplying the percentage of carbon obtained in a coal by 8,080 will give us the units of heat, but this will always be found to be too low, as hydrogen is always present in coal, more or less, which is available as fuel, making the results too low, and to be accurate an elementary analysis must be made.

EXERCISES.

1. What is the difference between an elementary and an approximate analysis?

2. How is the moisture in coal determined?

3. How is the volatile and combustible matter determined? The coke?

4. How would you determine the ash?

5. How is the amount of sulphur determined?

6. From the above analysis, from what do you find that the sulphur must be deducted?

7. How are the results from the above analysis reported?

8. What is a heat unit?

9. What is meant by the calorific power of coal?

THE PREPARATION OF PURE GOLD AND SILVER.

Pure gold and silver are necessary in all well regulated assay offices for the purpose of making check assays on bullion, and while proof gold can be purchased at most of the refining works at $40.00 per ounce, it can as well be manufactured by the assayer if he has had much experience in the business.

The best material to use is the gold cornet which is usually about .998 fine and the other 0.002 parts being silver, weigh out 1,000 of gold to which add 2½ parts of pure silver and from 10 to 12 parts of pure lead; cupel, anneal, and roll into a cornet. Boil in C. P. nitric acid of 27 Baume, for twenty minutes. The acid is poured off and the cornet washed several times with distilled water. The cornet now consists of gold with a trace of silver.

The gold is now weighed and placed into Erlenmeyer flask and aqua regia added. It will need 4 parts of the acid to 1 of the gold, by weight, to dissolve it. The acid is added gradually and slowly heated to boiling. When all is dissolved the contents are diluted with distilled water and allowed to stand for several hours. The clear liquid is now decanted off into a large porcelain dish; evaporate until all of the nitric acid and most of the hydrochloric acid is expelled; dilute largely with distilled water and filter through a heavy filter paper into a large glass beaker. Do not wash the filter, but leave any solid substance behind upon it.

Heat the filtrate nearly to boiling and add an excess of saturated solution of oxalic acid; let it stand in a warm place over night, when all the gold will be precipitated, and the liquid found colorless. It is then poured off and the

gold washed several times with warm water, then with strong ammonia water to dissolve the last trace of any chloride of silver that it may contain; the ammonia is then washed out with distilled water, and finally with dilute hydrochloric acid, and lastly again with distilled water, until the washings are sweet to the taste. It is now dried and melted in a clean clay crucible in which some borax has been melted to glaze the sides with borax glass. It is then cast into a mold which has been smoked for the occasion. This gold is found to be 999.96 fine.

The following is a later process taken from the Mining and Scientific Press, and seems to be equally as good and has the advantage of being much shorter:

"In the preparation of proof gold, after having dissolved several ounces of fine gold in nitro-muriatic acid, allow to stand several days that any silver chloride present may settle, filter the solution, then evaporate to crystallization as usual. The manner of converting gold from chloride to metallic constitutes the difference between this method and the old. After diluting copiously with distilled water, I place the solution in a receptacle from which it is allowed to pour slowly into a glass jar containing several pieces of pure aluminum; the gold is at once converted from chloride to metallic, a great amount of heat being generated. Remove the larger pieces of aluminum, pour off the solution, washing the gold precipitate several times to remove any acid. Then add muriatic acid, and heat to dissolve any small particles of aluminum, after which wash well to free from acid. Then dry and melt the gold, which should be proof, 1,000 fine if proper care has been exercised."

Pure silver may be made by precipitating the silver from its nitric acid solution by common salt solution and thoroughly washing with warm water, adding strips of zinc until the chloride all turns dark, becoming cement silver,

then add dilute sulphuric acid to dissolve any traces of zinc that may be left in it. Thoroughly wash, dry, and melt with two parts of chalk in a clean and covered crucible. Or the following process may be equally as good:

"In the preparation of proof silver, I select silver as free as possible from any gold, dissolve in nitric acid and allow to stand for several days that any traces of gold may completely settle; precipitate the silver as chloride, stirring well as precipitation takes place, thus causing the silver chloride to be finely divided; then pour off the acid solution and wash the precipitate well with water.

"Place several pieces of aluminum in this chloride of silver precipitate and add sufficient water to cover, then add a small amount of muriatic acid to start reaction; in a short time the chloride will be converted to metallic silver. Remove the larger pieces of aluminum and wash the silver, then add more muriatic acid, and heat to dissolve any small particles of aluminum; wash again well till all acid is removed, then dry and melt the silver, which should be 1,000 fine."

TO MAKE PURE LEAD FREE FROM SIVLER.

Dissolve (sugar) acetate of lead in warm water and place in it a strip of zinc; let stand for a few hours. The lead will deposit on the zinc (forming the arbor tree); remove the lead from the zinc and wash it with water and a little sulphuric acid, and last with water. Dry and melt for use.

PART III.

PROSPECTING.

For the past thousand years it has been the first duty of the miner to explore the surface of a country for minerals and metals. They are not only a necessity, but an actual measure of civilization, for it cannot be denied that the country which possesses the greatest weight of manufactured metal has attained a corresponding degree of civilization and influence in the world; neither can it be perpetuated without an inexhaustible supply. Remove the metals from the world, knowledge and power would at once relapse into barbarism.

In modern mining the business of a prospector and explorer is one of the most important and noble industries that man can engage in. To be a good prospector is in itself a business that requires many qualifications as well as much study and practice, and this has been one of my principal thoughts in writing this book.

NOTES OF INSTRUCTION TO THOSE IN SEARCH OF THE PRECIOUS METALS.

The prospector should observe the character of all loose rocks found in ravines and gulches, especially in eddies, which are of frequent occurence in mountain districts. In searching the sands washed down by the rivers, it is well to bear in mind that if the bed of the river which flows through a level or open country, yields fine gold dust, it will probably yield larger or coarser gold near the mountain, as the finer and lighter particles will float farther away.

Very commonly, in a canyon or gulch where gold is found, an accumulation of boulders or gravel may be noticed high up on the sides of the range, and more or less parallel to the bed of the creek. Portions of such deposits should be carefully examined by washing in a pan, as the gold-bearing matter, whether carried there in past ages by running water or glaciers, may contain gold in rich layers, called by miners the rim-rock, which is always a riffle for the deposit of gold.

Should there be several distinct deposits the lower stratum on the bed-rock would be the richest. It is advisable to remember that when gold is found in placers or hillsides, the chances are that gold veins traverse the neighboring elevations of land. Such elevations may prove profitable to work, but this is not necessarily the case.

Almost all the rich metal bearing gold veins are found chiefly in the rocks of an older date than those of the coal measures, although some in California are found in a more

recent formation, and the famous Comstock lode was, no doubt, formed by the hot alkaline waters as late as the tertiary period. Without entering into a discussion as to the formation or origin of quartz veins, I will say that the same law applying to veins in one district also applies to another as to their compass bearing. Consequently they are parallel, although some distance may separate one lode from the other.

In some mining districts the second series of veins run at right angles to the first and principal. Such lodes are either of a different nature of mineral to that of the first, or, if the same, are very poor in quality.

It is well, also, to remember that a true mineral vein is not likely to exist alone; but many more, either richer or poorer, may be found to form a mineral belt. For this reason the prospector should not set his affections upon one vein alone until he has examined the whole district to his entire satisfaction. In searching for veins, he should study the general geological formation of the country, the cutting landslides, the cliffs, the sides of valleys, the sections of banks exposed to view by the action of water, river beds, and dry channels, and if he fails to find samples of rich float-rock he should travel on as long as he can find similar rock. When no more is found he should then start up the hillside or mountain to discover the parent rock from which they came. Very frequently at the base of the hill or mountain there is a deposit in the soil washed down from more elevated ground. High up on the hill may be found the float-rock in the form of boulders, or detached portions of the vein, which would not be far from the ore in the place.

By taking notice, however, of the various undulations and drift, the prospector may come across outcrop on the steep side of the gully, or backbone of the ridges; and,

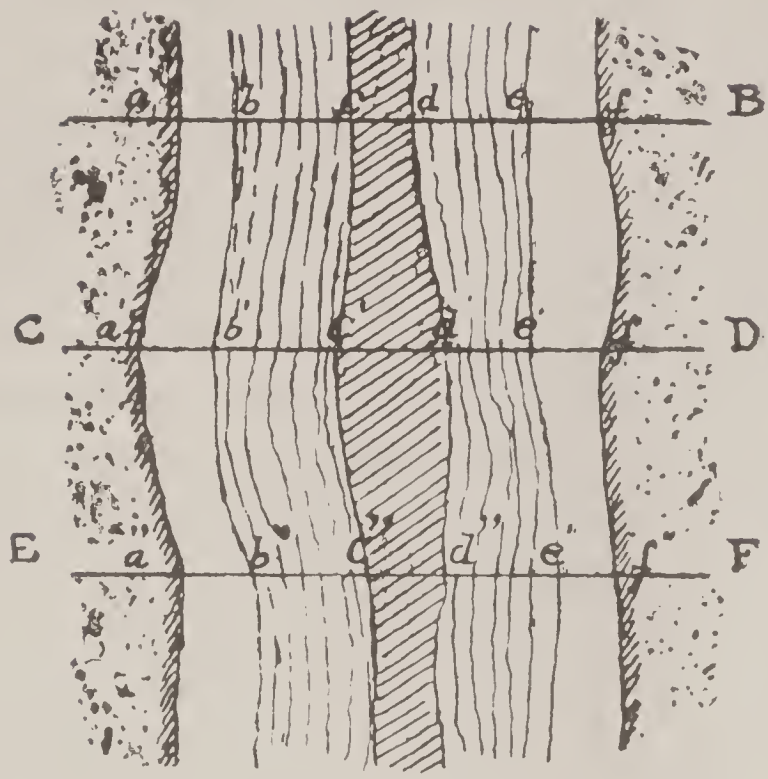
failing in this, he may travel toward the summit of any range of hills to find the vein.

Fluor spar (fluate of lime) is favorable for lead and copper; calc spar for lead and silver; but many other valuable minerals may be looked for in gulches and ravines, such as stream tin, antimonial silver, metallic copper, platinum grains, and telluride of gold; or he may travel across a section of the country where the strata are tilted and folded and metamorphosed, and the edges of a stratum for a considerable distance are upturned, so removing all doubts of its identity. Each section shows the strata as they succeed each other, and it supposes a cutting of them in the same manner that by cutting an onion we see the different coats of which it is composed.

All sections, when the contrary is not expressed, are supposed to be made perpendicular to a horizontal plane. In a plane, we lay down on a horizontal plane, the superficial area occupied by each bed as it rises to the surface, or, in the language of miners, bassets or crops-out.

We trace or delineate the superficial edges of strata by traveling across their basset edges, in a number of parallel lines, noting on a map made on a piece of paper, the several points at which we pass from one kind of rock to another.

Thus, in the annexed diagram, in crossing the country intended to be represented by it in the line A B, A being supposed to be situated on sandstone, we should pass at a from sandstone to limestone, at b from limestone to slate, at c from slate to granite, at d from granite to slate again, at e from slate to limestone, at f from limestone to sandstone again; and in traveling the same district along the lines C D and E F, we should find these changes take place at the points a, b, c, d, e, f, and a, b, c, d, e, f, respectively.



In this way the miner can construct a geological map of the country over which he may prospect, and fully determine its nature and mineral character.

For the gold-bearing vein there is none so good as the one which has an iron cap. The iron oxide is really the result of the decomposition of iron pyrites and the pyrites would be found deeper down after finding the vein. The prospector may dig a trench at right angles, if possible, to the lode, in order to examine its character, the nature of the ore and the gangue, and to find the boundary wall, viz., the upper and hanging wall, and the lower or footwall, as well as to note the direction or strike of the lode. He must sink a prospecting shaft a few feet deeper than the bottom of the trench to determine the exact body of the ore, as the lode may be distorted from its original shape near the surface. But when the direction of the lode is once ascertained, other pits, lower down, or higher up the hill, should be made so as to test the continuity of the vein. Should the vein prove continuous, and the surface assays turn out well, development may begin.

At the same time no person should be led away by the

hope that the deeper the vein the richer the ore. While it is a fact that lead and copper veins do improve by depth, and many gold veins have also, yet very many do deteriorate in value as they go down. But it is a recognized fact that veins vary in quality and nature, according to the strata through which they pass, and there are chances that the vein may "pinch out," or end in a "pocket," or become changed in character and value when least expected, and it is well to err on the safe side and never take your ore to an incompetent assayer to be tested, for many of the best assayers are often troubled to get the proper dressing in assaying-sulphurets, arsenical, or zinc ores. While the capitalist may risk his money in the chances he may take, the prospector's time and labor are worth too much to admit of his expending endless labor in obtaining experience in development work or on uncertain and unreliable assays.

If the lode carries gold or silver or other valuable metal, that fact is not enough to depend upon in estimating its worth. Often the gold is in very fine powder, invisible to the eye, or perhaps coated with a rusty film of silica, which would prevent amalgamation, and, in consequence, though the assay may be favorable, the extraction of the gold from the ore by amalgamation is not satisfactory, as the mercury may "sicken" or "flower." Again, the ore body may be rich enough, but much depends upon the nature of the other constituents. Antimony or arsenic may render it valueless. Before digging commences several samples of the rock should be taken from the lode and examined by an expert and reliable assayer, and the facts ascertained as to the value and quality of the ore, the best methods of treating it, etc. Unfortunately, this is not convenient in an out-of-the-way place. To assay correctly means a course of training. For this reason no one should undertake the

business unless he has practiced under the instruction of a competent assayer. Still, there is no reason why an inexperienced person should not attempt to qualitatively test minerals by some simple methods. To be compelled to go to a chemist, geologist, or mineralogist for every little matter of inquiry is not only inconvenient, but troublesome, as there are so many unreliable, so-called authorities to be met with.

Because some miner pronounces such a mineral to be unlike something he has seen in Cornwall or California, or some other place devoid of metal, the prospector need not be too ready to accept such an opinion, for, as a rule, the ordinary miner may be an expert in certain matters, like running a drift, timbering a tunnel, etc., but still may have erroneous notions about such minerals as gray copper ore, silver glance, fine or coarse grain galena, etc. The most experienced mineralogist cannot, for a certainty, tell at first sight, how much gold or silver may be in a particular rock. These metals are sometimes found in the most unlikely formations, and it is quite common to find a handsome, good-looking specimen which will disappoint everybody and carry nothing at all. Many of the silicates and carbonates and chlorides are perfectly unmetallic to look at, yet have been found very rich. For a long time the chloride of silver deposits in Colorado were passed over without being noticed, as was also the case with the carbonate of lead in Leadville, which, after discovery, in five years, converted Leadville into a city of 30,000 inhabitants.

After the prospector has discovered his vein of ore he must consider, before he thinks his fortune made, how far distant are fuel and water for successful operation. He must not grudge a little money in having a dozen or more of his samples assayed, and obtaining the advice of a proper assayer. He must remember that a low-grade ore in one

place is worth more than a rich one in another, and much more depends upon the character of the ore, whether it must be treated or not.

Another great mistake many miners and prosepctors make is in distributing their samples of ore from a mine among so many different assayers, in that the more assays a man makes from one mine, the better acquainted he becomes with the ore, the method of treating it, and the fluxes necessary to obtain the required results.

I have known some first-class assayers, who, being unacquainted with the ore, and not taking time to make a preliminary assay to determine its real character, make returns on a sample of steatite and quartz rock of only $12.00 per ton, when in fact it was really worth $25.00 or $30.00 per ton.

The miner should select the best assayer he knows of and stay with him, and not spend his time going around telling how such an assayer got more to the ton out of the same kind of rock from the same vein than some other assayer did. Such men are only exposing their ignorance among old mining men who know that gold is never equally distributed in a quartz vein, and that it is rarely, if ever, possible to get two assays to go alike even from the same pulp after sampling, and that the only reliable knowledge of the value of a mine can be obtained from the average of a large number of assays from it.

Nearly all the great mines have been found in the manner which I have described, and were rich to start with; if not, it is of but little use to dig in the earth to find a mine.

It is a well-known fact that all mountain regions where uplifts and foldings of strata and metamorphism have taken place, are favorable to the metal-bearing veins.

As for the geology of the country, much might be said, and much valuable information attained by miners and

prospectors in their search for the precious metals; and their observations extended and generalized have given us a large amount of knowledge as to the structure of the earth. The depth, however, to which this structure is laid open by the hand of man, is extremely limited; the deepest mine in the world penetrates little more than half a mile.

The convolutions which the earth has undergone has exposed its structure to a much greater depth. In cliffs, on the sides of ravines, on the banks of rivers, and on the seashores, the strata may frequently be seen resting upon one another in an inclined position, their original state having been disturbed by a force acting from below.

These natural sections often extend for many miles, and the inclination of the beds causes them to emerge successively to the surface, and enables us to estimate the thickness of the whole series of beds.

These beds may have been thrown up and pierced by volcanic rocks of the granite type, in large masses forming the axes of greater mountain ranges, as the Sierra and Colorado ranges, appearing in the midst of stratified rocks like islands in the midst of the sea.

These plutonic rocks in many places may never have penetrated the strata, but merely raised and folded them and afterwards have been sculptured and worn away as above described.

Fissures, passing through many strata and many formations, are produced by shrinkage in the earth's crust, and are, therefore, often many miles in length and many feet in width and pass downward to unknown depth. Evidently the cause of great fissures is the usual folding or wrinkling of the crust of the earth produced by the contraction of the interior portion. The natural tendency of such folding would be to form a parallel system of fissures in the direction of the folds, and so at right angles to the folding force

Fissures are thus found in systems parallel among themselves and at the axes of the mountain chains.

Heat is a necessary agent in forming a quartz vein as well as changing the nature of the abounding rock from a crystalline structure to a metamorphose condition. Thus hundreds of miles of rock are universally changed. The only theory by which the formation of a quartz vein can be established is by the hot alkaline solutions highly charged with silica. This is plainly evident from the material of the vein itself. The ribbon structure and the interlocked crystals suggest at once successive deposits from solution, especially as a similar structure occurs in filling all kinds of cavities which could not have been filled in any other way.

Quartz is the most common of all vein matter. There are two varieties of silica, one having a specific gravity of 2.2, the other 2.6; the former is quartz glass, the latter is the true quartz, and cannot be formed except by the humid way, and has always been produced by slow deposition from solution, and the specific gravity is always 2.6. The beautiful crystals of the former often found could be formed only by crystallization at a low temperature, as they will not stand fusion.

Fissures running deep into the interior of the earth could not remain free from water, and must necessarily be highly heated, and it has been determined that there must be a temperature of between 200 and 350 degrees, centigrade, which would dissolve almost any substance. These heated waters are strongly alkaline carbonates and alkaline sulphides which are the only solvents for quartz. An abundance of these springs now exist all over the country, but are now much cooler than formerly, although still depositing silica (quartz) and carbonates of lime, cinnabar and iron. All these metals found in quartz veins must have

been deposited by the same solutions that deposited the quartz. The metallic sulphides are the most common form of ore, and they come in contact with the hot solutions of the alkaline carbonates, meeting and coming together in the same fissure with other waters containing metallic sulphides which would precipitate the metals. These iron sulphates come from the oxidation of sulphides, and the sulphides from the deoxidation of the sulphates. This is only an example of the perpetual cycle of change.

* "Again, the gold in the vein is leached from the strata which received it from the sea; but again, doubtless, the sea received it from the rocks, and this brings us to another perpetual cycle of change. In the strata the quantity of gold is so small as not to be detected, but yet abundant enough to furnish all the gold in existence. From thence it is carried and concentrated in the vein in a still more available form; following the disintegration of the vein it is carried down by the currents along with other material, neatly sorted out and deposited in the placers in a yet more available form."

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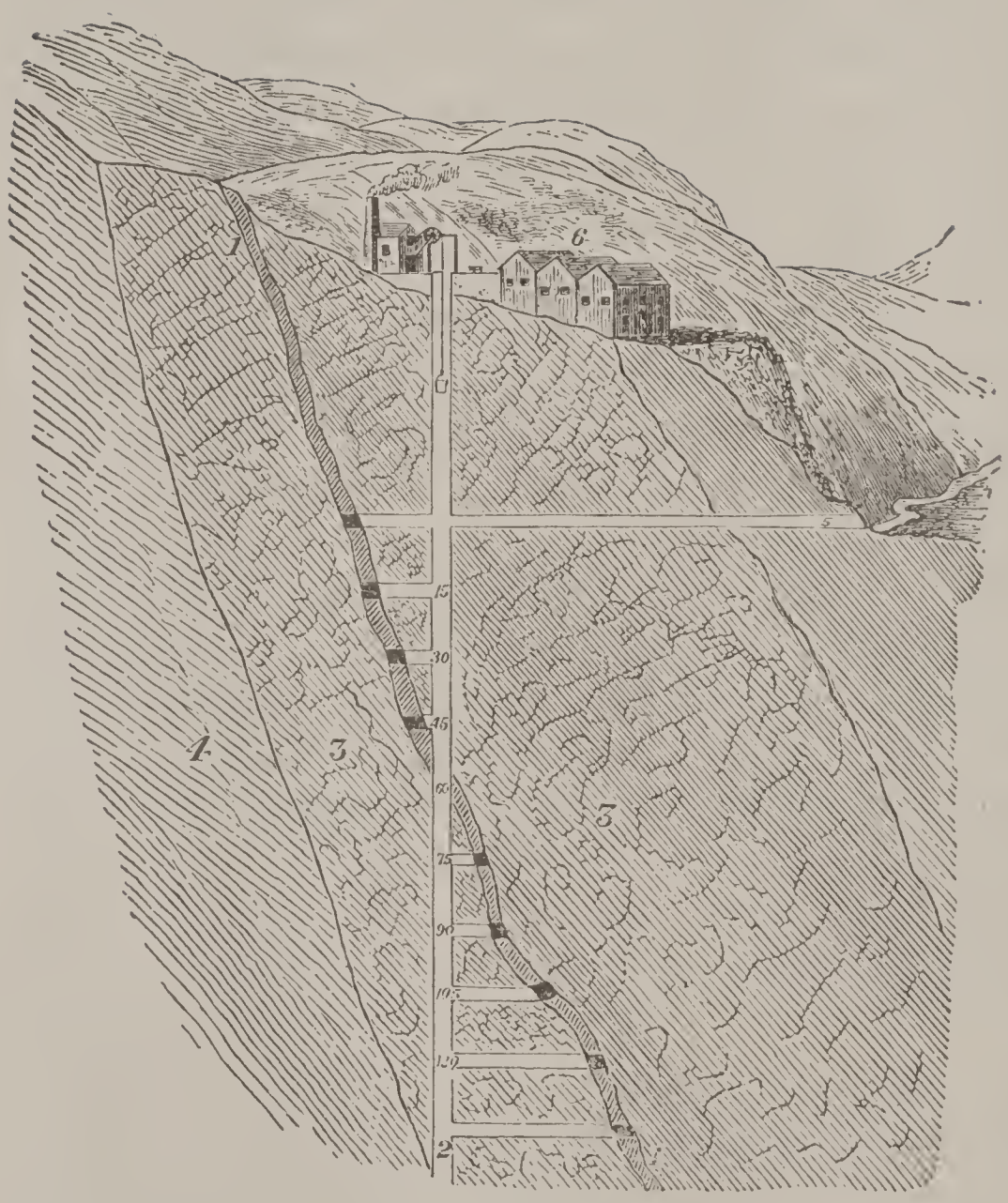
*Le Conte.



LODE WORKED BY VERTICAL SHAFT.

1, Lode. 2, Shaft, 15—120 fathoms cross-cuts. 3, Productive Strata. 4, Unproductive Strata 5, Adit Level. 6, Dressing Sheds.

SYNOPSIS OF SOME OF THE RARER AND LESS WELL-KNOWN METALS.

1. GOLD is generally supposed to be the most valuable of metals, but this is a mistake; for, while it may be one of the oldest metals known, it is far from being the most precious. Its discovery is shrouded in the darkness of the early ages, and it is the only metal of a yellow color. It is frequently alluded to in the Old Testament; the Jews refined it by cupellation, a process which has never been improved upon. Jewelry and vessels of it have been found in Egyptian tombs, which afford evidence of its use before the government of Joseph. Pliny speaks of separating it by amalgamation with mercury.

The United States government places a valuation of $20.67.18 per ounce or about $250.00 per pound.

2. SILVER.—The discovery of silver appears to have been coeval with that of gold, and dates back to the earliest times of the world's history. In the book of Genesis we learn that silver was current money with the merchants, about 2000 years before the Christian era, and frequent mention is made of this metal in the subsequent books of the Bible. The metal is always found alloyed with gold, and gold with silver. Evidently nature intended bimetalism. Silver is worth, at the present time, about $12.00 a pound.

3. PLATINUM.—The metals platinum, palladium, rhodium, iridium, ruthenium, and Osmium are united in a

family by a striking similarity in chemical character and by their association in natural occurrences.

4. A rather rare ore, called platinum ore, or polyxene, is almost the only native material which is available for their extraction; it contains them all in the reguline form. The metal platinum is an exceedingly useful metal, very ductile and malleable; two pieces of the metal can be welded together at a white heat, and it requires the oxyhydrogen flame to melt it. Its value is about $130.00 per pound.

5. NICKEL. The metal is obtained chiefly from nickeliferous iron pyrites (magnetic variety) which only contains the element as an accessory constituent. The native arsenides, an impure regulus (called speiss) formed in the preparation of smalt, are the other sources of the nickel of commerce. Metallic nickel Sp. Gr. 8.82, has a silver-white color, brilliant metalic lustre, and does not tarnish when exposed to the atmosphere. Its value is about 60 cents per pound.

6. ALLUMINUM is readily obtained by reducing either the chloride or the native fluroide (cryolite) with metallic sodium. It has a brilliant white lustre, and possesses to a high degree all the qualities of a useful metal. It has a low Sp. Gr. of 2.56 and a very great tenacity, and its value is from 50 cents to $2.00 per Troy pound.

These values sink into insignificance in comparison to the value placed upon some of the less known metals, owing to the cost of separating them from their ores.

7. BARIUM.—This metal decomposes cold water with the evolution of hydrogen.

8. But less readily than the alkaline metals. Barium salts communicate an apple-green color to the blowpipe flame. Strontium salt gives a brilliant crimson color, and calcium salt an orange-red color to the flame. The metal barium sells for $950.00 a pound.

9. CALCIUM is a yellow metal of the color of gold, largely alloyed with silver. In hardness it is intermediate between lead and gold, and is very ductile, and melts at a red heat. It is worth $1800 a pound.

10. CHROMIUM.—This metal is extracted from the ore chromate of iron, a massive and compact granular, crystaline black-colored mineral Sp. Gr. 4.4, and hardness 5.5. It occurs usually in serpentine. The metal is worth about $200 per pound.

11. CERIUM, LANTHANUM, AND DIDYMIUM. These three rare elements are found inseparably united in serite, allanite, lanthanite, yttrocerite, parasite, and several other very rare minerals. In regard to the elementary substances but little is known. Cerium, which has been obtained by reducing its chloride with sodium, is a soft metal like lead. When polished it exhibits a high metalic lustre and its Sp. Gr. is about 5.5 and worth $160 per ounce or $1920 per pound.

12. DIDYMIUM was isolated by Masander and is worth about $1800 a pound.

13. CALUMBIUM (Niobium).—This element forms the acid radical of calumbite, samarskite, euxenite and a few other rare minerals, with various metallic oxides. It has a black color, a submetallic lustre and a Sp. Gr. from 5.4 to 6.5. When finely powdered it is easily decomposed by fusion with potassic bisulphate.

14. The metal calumbium is a black powder. An infusion of nut-gall gives, with acid solutions containing calumbium, a deep orange-red precipitate. It is valued at $120 per ounce.

15. GLUCINUM.—A metallic element found in Beryl. The metal is very light (Sp. Gr. 2.1), is malleable, has a bright white lustre, does not alter in the air, even when

heated. It resembles aluminum, and is worth $250 per ounce, when sold.

16. GALLIUM.—This metal was discovered by means of the spectroscope in zinc blend.

17. The metal is bluish and has the remarkable property of fusing at 30.1 degrees. The molten metal resembles mercury and remains liquid for several weeks even at 0°. If, however, the globule is touched with a small fragment of the solid metal, it at once crystallizes. But, although so fusible, gallium is not volatile at a red-heat. The Sp. Gr. of the metal is 5.9. It is worth $3,250 an ounce and is rarest and most precious of all known metals.

18. INDIUM.—This metal is another associate of zinc found in blend, and, like gallium, was discovered with the spectroscope. It takes its name from well-marked indigo-blue bands which its flame shows when examined with this instrument. The metal is softer than lead. Sp. Gr. 7.42. It has a white metallic lustre, which it retains in the air. The best solvent is nitric acid.

19. Heated on charcoal before the blowpipe, it colors the flame blue and gives an incrustation of the oxide.

20. IRIDIUM is a very hard, white, brittle metal and found in the black sands in gold washings. Sp. Gr. 21.15. The pure metal is not acted on by any acid; but, when alloyed with platinum, it dissolves in agua regia. It may be rendered soluble by fusion with alkaline reagents. Its value is $658 a pound.

21. LITHIUM, RUBIDIUM AND CAESIUM are found in minute quantities in certain mineral water, in lepidalite mica and in a few other rare minerals. They are always associated with potassium and sodium, to which they are closely allied in their chemical relations. The metal lithium is remarkable as being the lightest solid known. Its Sp. Gr.—0.59; its value is $160 per ounce.

22. OSSMIUM.—In the most compact condition in which this metal has been obtained it has an Sp. Gr. of 21.4 and a bluish color much like zinc. It has never been fused, but it slowly volatilizes at the temperature at which ruthenium and iridium melt. When in powder, ossmium is very combustible. It will take fire at the melting point of zinc. It is one of the most poisonous substances known. Its value is $640 a pound.

23. PALLADAIUM is a brilliant white metal, resembles platinum more closely than either of its associates, although best known as a subordinate constituent of platinum ore. It is harder than platinum, has less tenacity and is not so ductile. Nevertheless it can be wrought with facility. The quantity of hydrogen "acculated" by palladium amounts to nearly one equivalent of the metal and produces a marked change in its physical qualities. From these facts Professor Graham inferred that the metal charged with gas is an alloy of palladium and metallic hydrogen, which he called hydrogenium. Its value has not been determined, to my knowledge.

24. TANTALUM is associated with calumbium in the native calumbates. The chief constituent is Tantalite, which has a higher Sp. Gr. than calumbite, which varies from 7 to 8. By reducing sodio-tantalic fluride with sodium a black powder is obtained, which is metallic tantalum, and worth $144 per ounce.

25. TELLURIUM is closely allied to Selenium, and both closely allied to sulphur. Selenium, in its elementary state, is a brittle solid, having a glossy fracture and a brown color, Sp. Gr. 4.3. But in tellurium we find a more marked difference. The elementary substance is a silver-white color, a bright metallic lustre and apparently a metal. Its Sp. Gr. equals 6.2: its value is $9 an ounce.

26. THORIUM.—The mineral thorite, an orangite, is a

hydrous silicate of this rare metallic element, which has been found as a subordinate constituent in euxenite, monazite, gadolinite and orthite. The unhydrous oxide is a white powder which glows when heated and becomes more dense. The chloride may be reduced by sodium, and the metal may be thus obtained as a gray lustrous powder which readily burns in the air. Its value is $272 per ounce.

27. THALLIUM is a very rare element found in varieties of pyrites and crookesite. A selenide of copper and thallium form a copper mine in Sweden. But thallium has not as yet been isolated as a metal, to my knowledge.

28. VANADIUM was discovered in 1830 in the iron ores of Sweden. It has been found associated with lead and copper and termed the vanadates of these metals. It resembles the native phosphates and arsenates. Oxides of vanadium are a brown crust formed by prolonged exposure of metallic vanadium to the air and looks much like metallic copper. It is found to be quite extensive near Farmington, in Washington. The metallic powder has a Sp. Gr. equal 5.5 Its value is $320 per ounce.

29. YETTRIUM. ERBIUM and their associates.—These rare minerals, gadalinite, euxenite, keilhanite, and lamarskite, contain a mixture of earths which quite closely resemble glucina. Very little of these elements is yet known; but several able chemists are investigating the subject and no doubt soon we will have more definite information regarding them. Yettrium is said to be worth $144 per ounce.

30. ZIRCONIUM.—The powder metal burns rapidly in air. The crystalline metal requires to be heated in an oxyhydrogen flame, if it is to catch fire. Its Sp. G. is 4.15. When heated to whiteness it remains unfused, and radiates an abundance of white light. This property has been utilized for the construction of a new kind of gaslamp, in which

a colorless flame, produced by the combustion of a mixture of gas and air, serves to heat a hollow cylinder of zirconia suspended over it by means of a platinum gause. Its value is $250 per ounce.

Many other metals have also been discovered, but no value can be placed upon them, as they have yet found no commercial value, but no doubt in the future the list will be greatly increased. The analysis of these ores belongs to the chemist, and not to the average asayer, and the synopsis of them is merely inserted here for information, as I have often been called upon for information concerning them.

(1) What can you say of Gold? Its origin, its use in the arts and coins; its purity and allies, and Sp. Gr.?

(2) What can you say of Silver? Its history, purity, and the kind of ores in which it is found; and natural allies, and its Sp. Gr.?

(3) What are the native associates of Platinum ore? What is the name of the ore, and its Sp. Gr.?

(4) What is the character of Platinum as a metal, and how can it be melted? What is its value and Sp. Gr.?

(5) From what ores is Nickle found, and what is its native ally?

(6) How is Alluminum obtained? What is the character of the metal, and its Sp. Gr.?

(7) What is the color of the B. P. Flame of Barium Salts, and how will you distinguish it from Strontian?

(8) What is its action on water, and what is its value?

(9) What is the color of the metal Calcium? At what does it melt; and what is the character of the metal, and its value?

(10) From what kind of ore is the metal Chromium extracted? What is its use and value, and Sp. Gr.?

(11) What kind of ores are Cerium and Lanthanum found in? How is Cerium obtained from the ores? What

is the character of the metal? Its value and Sp. Gr.?

(12) What can you say of Didymium?

(13) What is the character of the metal Columbium? How is it obtained from the ore, and what kind of ores?

(14) What is the test of Columbium in an acid Solution? What is its Sp. Gr., and its value?

(15) From what kind of ore is Glucium obtained? What character is the metal? What metal does it resemble? And what is its value?

(16) How was the metal Gallium discovered, and in what ores is it found?

(17) What is the color of the metal Gallium? What is its character, its fusing point? What is its Sp. Gr., and its value?

(18) What ores is Indium found in? What is the character of the metal and its Sp. Gr.?

(20) What is its flame color, and how is Indium obtained? What is its Sp. Gr.? How is it made Soluble, and what is its value?

(21) In what ores is Lithium, Rubidium and Caesium found? What is the Sp. Gr., of Lithium, and its value?

(22) What is the Sp. Gr. of Ossmium? What is the color of the metal, its character and value?

(23) What kind of metal is Palladium? What is its character, and what does it combine with?

(24) What is Tantalum associated with, and how is it obtained from the ore? What character is the metal? What is its Sp. Gr., and value?

(25) From what mineral is Thorium obtained? What is the appearance of the metal, and how is it reduced?

(26) What kind of ores is Thallium found in?

(27) When was Vanadium discovered?

(27) When was Vanadium discovered? What is it asso-

ciated with? Where is it found in this country? What is its Sp. Gr., and value?

(28) What kind of ores are yettrium found in, and what is known of it?

(29) Describe the ore of Zirconium? What is its Sp. Gr.? What is its use and value?

PRELIMINARY EXAMINATION OF ORES.

All minerals and substances submitted to the assayer for analysis should first undergo a preliminary examination to determine the character and mineral constituents, thereby showing what is the best method of treatment, and, in making out his report to his patron, he should briefly inform him of these facts as well as the results of his assay.

Sometimes this preliminary examination is unnecessary when an ore is submitted with a statement of its character and the constituents required to be determined. Where the ore is in a lump form, the assayer, if he is competent, can at once determine its chief constituents by an eye examination, but for practical use and experiment, I here-with give a few tests of the most common ores, by both the wet and the dry method.

The ore to be tested should be first ground to a fine powder in an iron or steel mortar, although in some cases the original rock will do.

ALUMINA.—The metal is never found in the native state, but in combination with silica and corundum. Sapphire and ruby are nearly pure alumina; emery is an impure alumina; beauxite is a red hydro-silicate of alumina. It may well be detected, when dry, by applying it to the tip of the tongue and suddenly withdrawing it. If alumina be present, it will reveal its desire for moisture by adhering to the tongue. Before the blowpipe, when moistened with nitrate of cobalt, it will give a clear, blue color to the flame. Take a little of the powdered alumina and dissolve it in nitric acid by warming, then filter it, and you have a clear liquid. Add a little ammonia to neutralize it, which will

give a gelatinous precipitate of alumina hydrate, insoluble in excess.

CARBONATE ORE. — Place a drop of strong acid upon the rock. If it effervesces or boils up, it contains carbonate. Place some of the powdered ore in a test tube with acid, and hold over it a glass rod previously dipped in lime-water; the drop on the rod will turn milky, showing formation of carbonate of lime. It is easily precipitated with oxalate of ammonia, but insoluble in acetic acid. It gives a white precipitate with dilute sulphuric acid, and is soluble in strong sulphuric acid.

TELLURIUM.—It is found native, also combined with gold, silver, lead, and antimony. To test the ore, take a small piece and place it on any white piece of crockery—a broken plate will do—and heat it with the blowpipe flame for a few minutes; now place a drop of strong sulphuric acid on the dish, and let it slide down to the heated fragment. As soon as it touches the ore, a beautiful carmine color is visible, and when cold the color will fade.

TELLURIDES IN GOLD ORES.—Heat the powdered mineral in a test tube with charcoal, carbonate of soda, and hot water. If telluride be present, it is known by the solutions being purplish red in color; boiling in sulphuric acid affords a pinkish solution.

TIN ORE.—There are two kinds of tin ore—oxide and sulphide. It may be suspected by its specific gravity which is 4.3 to 7.1 The oxide is the heaviest. In color, it varies from an almost white to a dark brown, and through all the shades of rosin. It may be distinguished from iron by being soluble in aqua regia. With borax and carbonate of soda on charcoal, it will give you a globule of tin. For a good test, it is best to mix some of the powdered ore with twice its weight of cyanide of potassium in a crucible, and fuse it in a forge, when a button of tin will be obtained.

SULPHUR—Melts with soda on charcoal. Moistened and placed on a silver coin, a dark stain indicates sulphur, but if selenium be present it will do the same. To distinguish them, heat some of the powder to redness in the scorifier; if it does not smell like a burning match the sulphur is not in the form of a reducer.

SULPHATES.—To some of the powdered rock add nitric acid; warm, and filter. Divide the filtrate into two test tubes. To one add a solution of chloride of barium. If lead be present add nitrate of barium to the other. After standing a while, a white, cloudy precipitate shows sulphates to be present.

ZINC.—Sulphide of zinc dissolves readily in dilute solutions of hydrochloric acid and sulphuric acid with evolution of hydrogen gas. Before the blowpipe on charcoal it leaves a white oxide of zinc, which is white when hot and yellow when cold. With chloride of zinc, if you add salt, then cobalt, it gives a green-colored mass. Throwing some of the ore into the fire will give a brilliant white flame.

MANGANESE—Disolved in nitric or hydrochloric acid gives a faint pink color. Filter it off, and to the filtrate add sulphide of ammonia. It will then give a flesh-colored precipitate off the sulphide of manganese. Before the blowpipe, compounds of manganese color the borax bead amethyst in the oxidizing flame. If manganese be fused with alkalies, it will give a green manganate color, but the solution in all cases will be pink or flesh-color when an acid is added to it.

IRON ORE.—Dissolve the powder with nitric or hydrochloric acid, filter, then dilute with water and divide into three test tubes. To one, add a drop of sulpho-cyanide of potassium and a blood-red coloration takes place. To another add a little ammonia water and a reddish-brown gelatinous mass forms. To the third, add a little of a solu-

tion of yellow prussiate of potash; a blue precipitate will occur. This proves conclusively the presence of iron compounds.

COPPER ORE.—This will soon dissolve in nitric acid, but very slowly in hydrochloric acid. All copper carbonates are either blue or green. The blue copper is azurite, but the green is malachite. They are both carbonate ores. When dissolved in nitric acid, add ammonia water, and it will turn an intense blue color; or place in a dilute solution of copper a little yellow prussiate of potash, and it will give a mahogany-colored precipitate; or place in a dilute solution a piece of bright iron, and it will be coated with copper. If it were nickel ore, the green, as it came from the acid, would be an apple-green, and would give a precipitate with ammonia. With the blowpipe, as a conclusive test, it will color the borax bead green when hot. Moisten the powdered ore with salt brine, and throw into the fire; an intensely blue flame will be seen.

ANTIMONY.—Is scarcely attacked by either nitric or hydrochloric acid, but will readily dissolve in both when mixed together (three parts of hydrochloric to one of nitric-aqua regia); then add water, which will precipitate a base of chloride of antimony. With the blowpipe, it is distinguished by its extreme fusibility and vapor. In the candle flame, it gives off a white coat on charcoal, extending a long way and easily driven about by the flame. Globules, if obtained, thrown on a table, while hot, roll along giving off dense white fumes.

NICKLE ORE.—It is very hard to distinguish it unless in the hands of a competent assayer. The pale green oxide is (garatite, zaratite or genthite) copper nickel combined with copper; another is arsenical nickel combined with arsenic. It will dissolve in nitric acid; will give a pale-green oxide when filtered from its acid solution; will give a

pale-green precipitate with yellow prussiate of potash. The copper nickel is pale copper-red, but it has to be purified from other metals before any satisfactory test can be made of it. It may be somewhat indicated by the blowpipe on charcoal. The borax bead will be blue if cobalt predominates, and brown if nickel predominates, as they are most always associated together.

LEAD ORGALENA ORES.—Drop a little nitric acid on the ore, then add a little water, then a crystal of iodide of potassium; a bright yellow precipitate will at once form, which shows lead to be in the ore. These tests can all be shown with the filtered solution in the test tube if dissolved in acid. The chromate of potash gives a precipitate of lead which is yellow chromate of lead. Add salt to the solution with nitric acid, you have a granular precipitate.

SILVER ORE.—Boil the powdered ore and filter it. Drop into it a little salt water or hydrochloric acid; it forms chloride of silver; a white curdy precipitate of the chloride of silver is thrown down. This is a good test for all silver ore, except the chloride ores. This kind of ores, powdered, should be placed in a test tube with strong ammonia water, and corked, being allowed to stand for a few hours. Then add nitric acid in slight excess, then salt water, and the chloride of silver will soon fall down forming a milky white precipitate. Boil the powdered ore in a glass flask with a strip of clean copper, bluestone, and salt water. This will give a white coat on the copper.

TEST FOR GOLD BY WET METHOD.—The powdered ore must be boiled a little while in aqua regia (3 parts of hydrochloric and 1 part of nitric acid). A purple precipitate will be found when proto-chloride of tin is added to the solution, which is purple of cassius.

GOLD.—The best test of gold is the fire assay. When an assay office is not convenient, the best way is to grind

the rock to a fine powder, add a little potash, put it into a saucer or a small pan or dish of any kind, and when nearly all panned down examine closely for fine colors of gold.

IRON OR COPPER SULPHURETTES.—The best way to test these for gold is to boil the powdered mineral in strong caustic potash, then wash or pan it out as before mentioned, and examine for fine colors of gold.

CINNABAR.—Mercury is not always, but most always combined with sulphur. It may be detected by either the dry or the wet way. In the dry way, place some of the powdered ore in a test tube with an iron nail, and heat it over the lamp flame, holding over it a bright strip of copper. Take the copper out and rub it with the finger or bit of cloth or paper, and it will give a bright luster.

BISMUTH.—The ore bismuth is more fusible than lead, and is easily reduced in the yellow flame of the blowpipe; with carbonate of soda gives a reddish-white metal; when dissolved in nitric acid, water will precipitate as white oxide. This is the only metal besides lead which can be cupelled alone.

CHROMATE OF IRON.—Place some of the powdered ore in a test tube with nitric acid and boil. It will color the acid green; then filter, and to the filtrate add ammonia, which will precipitate in dirty green flakes, which will redissolve in acid compounds of chromium. With the blowpipe, will color the borax bead green. The precipitate with ammonia—if fused with a little potash and soda—will give a yellow mass of alkali chromate. The ore, if fused with potash and soda (carbonates), gives a yellow precipitate with lead salts, red with sulphur compounds, and turns green by boiling with hydrochloric acid and alkali.

ARSENIC.—Powder the ore; throw it on live coals or a hot shovel, or within the blowpipe flame; it will give a garlic smell.

SELENIUM.—Test the same as for arsenic and it will give a smell of rotten horseradish.

GYPSUM, HEAVY SPAR—Is an earthy sulphate; scratches with a knife and is not affected by acid. The best test of sulphur is on silver, but will not smell of it.

BORATES OR BORAX, OR BORATE OF LIME.—Moisten with glycerine, will give a green flame with the blowpipe; or treat with sulphuric acid in a dish, then add alcohol and set fire to it and a green flame will appear.

GLOSSARY OF THE MOST IMPORTANT MINERALS, GIVING THE FORMULÆ, HARDNESS, SPECIFIC GRAVITY, AND BEHAVIOR WITH ACIDS.

I=insoluble in or unaffected by acids; S=soluble in or decomposed by acids.

Formula.		Name.	Hardness.	Specific Gravity.	Crystalline System.
$Al_2O_3.3SiO_2+Na_2O.3SiO_2$	I	Albite	6	2.6–2.67	Triclin.
$RO.R_2O_3.4SO_3.24H_2O$	S	Alum	2–2.5	1.75–1.9	Tess.
$C_{10}H_8O$	S	Amber	2–2.5	1.0–1.1	Irreg.
$Al_2O_3.3SiO_2+Na_2O.SiO_2+2H_2O$	S	Analcime	5.5	2.1–2.25	Tess.
$Al_2O_3.SiO_2$	I	Andalusite	7–7.5	3.1–3.2	Rhomb.
$PbO.SO_3$	S	Anglesite	3	6.2–6.35	Rhomb.
$CaO.SO_3$	I	Anhydrite	3–3.5	2.8–3.0	Rhomb.
$Al_2O_3.SiO_2+CaO.SiO_2$	S	Anorthite	6	2.7–2.76	Triclin.
C, H, N, O, &c.	—	Anthracite	2–2.5	1.4–1.7	Irreg.
Ag_2S	S	Argentite	2–2.5	7.0–7.4	Tess.
$CaO.CO_2$	S	Arragonite	3.5–4.0	2.9–3.0	Rhomb.
C, H, N, O, &c.	—	Asphaltum	2	1.1–1.2	Irreg.
$(Ca.Mg.Fe)O.SiO_2$	I	Augite	5–6	3.0–3.5	Monoclin.
$(Al.B)_2O_3+2(Ca.Fe)O.SiO_2$	I	Axinite	6.5–7	3.2–3.3	Triclin.
$3CuO.2CO_2+H_2O$	S	Azurite	3.5–4.2	3.7–3.8	Monoclin.
$BaO.SO_3$	I	Barytes	3–3.5	4.3–4.7	Rhomb.
$Al_2O_3.3SiO_2+3(GlO.SiO_2)$	I	Beryl	7.5–8	2.6–2.8	Hexag.
$Al_2O_3.SiO_2+3(Mg.K_2.Ee)O.SiO_2$	S	Biotite	2.5–3	2 85–2.9	Hexag.
CH_2	—	Bitumen		.7–9	Liquid.
$Na_2O.2B_2O_3+10H_2O$	S	Borax	2–2.5	1.7–1.8	Monoclin.
$3Cu_2S.Fe_2S_3$	S	Bornite	3	4.9–5.1	Tess.
C, H, N, O, &c.	—	Brown Coal		.5–1.5	Irreg.
$2Al_2O_3.P_2O_5+5H_2O$	S	Calaite	6	2.6–2.8	Irreg.
$CaO.CO_3$	S	Calcite	3	2.6–2.8	Hexag., Rhombo.
SnO_2	I	Cassiterite	6–7	6.8–7.0	Tetrag.

GLOSSARY OF THE MOST IMPORTANT MINERALS—Continued.

I=insoluble in or unaffected by acids; S=soluble in or decomposed by acids.

Formula.	Name.	Hardness.	Specific Gravity.	Crystalline System.
$SrO.SO_3$	I Celestine	3–3·5	3·9–4.0	Rhomb.
$PbO.CO_2$	S Cerussite	3–3·5	6.4–6.6	Rhomb.
$2(2RO.SiO_2)+Al_2O_3.3H_2O$	S Chlorite	1–1.5	2.78–2.96	Hexag.
$(Fe.Mg)O.(Cr.Al)_2O_3$	I Chromite	5·5	4·4–4·5	Tesseral.
$2(Mg.Fe)O.SiO_2$	S Chrysolite	6.5–7	3·3–3·5	Rhombic.
$K_2O,Al_2O_3,H_2O,Fe_2O_3,CaO,SiO_2$,&c.	— Clay		1.8–2.7	Irreg.
CoS_2+CoAs	S Cobaltine	5·5	6.0–6.3	Tess.
$2Al_2O_3.3SiO_2+2(MgO.SiO_2)$	I Cordierite	7–7·5	2.5–2.7	Rhomb.
Al_2O_3	I Corundum	9	3·9–4.2	Hexag., Rhombo.
Cu_2O	S Cuprite	3·5–4	5·7–6.0	Tess.
$Al_2O_3.SiO_2$	I Cyanite	5–7	3·5–3·7	Triclin.
$CuO.SO_3+5H_2O$	S Cyanose	2.5	2.2–2.3	Triclin.
$CaAO.B_2O_3+CaO.2SiO_2+H_2O$	S Datholite	5–5.5	2.9–3.0	Monoclin.
C	I Diamond	10	3·5–3.6	Tess.
$CaO.CO_2+MgO.CO_2$	S Dolomite	3·5–4·5	2.85–2.95	Hexag., Rhombo.
$Al_2O_3.3SiO_2+3(GlO.SiO_2)$	I Emerald	7 5–8.0	2.6–2.8	Hexag.
$MgO(FeO).SiO_2$	I Enstatite	4·5–5·5	3·1–3·3	Rhomb.
$3(Al_2O_3.SiO_2+CaO.SiO_2)+CaO.H_2O$	S Epidote	6–7	3·2–3·5	Monoclin.
$3CoO.As_2O_5+8H_2O$	S Erythrine	1.5–2.5	2.9–3.0	Monoclin.
CaF_2	S Fluorite	4	3·1–3·2	Tess.
$Al_2O_3,(Fe,Mg,Ca,H_2)O,SiO_2$,&c.	— Fullers' Earth	1–1.5	1.8–2.0	Irreg.
PbS	S Galena	2.5	7.2–7.6	Tess.
$2ZnO.SiO_2+H_2O$	S Galmei	5	3·3–3·5	Rhomb.
$3(Mg.Ca)O.2SiO_2+(AlFe)_2O_3.SiO_2$	S Garnet	6.5–7·5	3·5–4·3	Tess.
$ZnO.SO_3+7H_2O$	S Goslarite	2–2.5	2–2.1	Rhomb.

GLOSSARY OF THE MOST IMPORTANT MINERALS—Continued.

I=insoluble in or unaffected by acids; S=soluble in or decomposed by acids.

Formula.	Name.	Hardness.	Specific Gravity.	Crystalline System.
$Fe_2O_3.H_2O$	S Gotheite	5–5.5	3.8–4.4	Rhomb.
C	I Graphite	.5–1	1.9–2.2	Hexag. or Monocl.
$BaO.Al_2O_3+5(H_2O.SiO_2)$	S Harmotome	4.5	2.3–2.5	Rhomb.
$2(Al_2O_3.SiO_2+Na_2O.SiO_2)+CaO.SO_3$	S Hauyne	5–5.5	2.4–2.5	Tess.
$Al_2O_3.3SiO_2+CaO.3SiO_2+5H_2O$	S Heulandite	3.5–4	2.1–2.2	Monoclin.
$(Mg.Fe.Ca)O.SiO_2$	I Hornblende	5–6	2.9–3.4	Monoclin.
$6(2RO.SiO_2)+2Al_2O_3.3SiO_2$	S Idocrase	6.5	3.35–3.45	Tetrag.
$FeO.TiO_2+xFe_2O_3$	S Ilmenite	5–6	4.3–5.0	Hex., Rhombo.
$H_2O.Al_2O_3+H_2O.2SiO_2$	S Kaolin	1	2.2	Irreg.
$Al_2O_3.2SiO_2+RO.SiO_2$	S Labradorite	6	2.6–2.74	Triclin.
$SiO_2,SO_3,CaO,Al_2O_3,Na_2O,$&c.	S Lapis-lazuli	5.5	2.3–2.42	Tess.
$Al_2O_3.SiO_2+Li_2O.SiO_2$	S Lepidolite	2–3	2.5–3.0	Monocl. Rhomb.
$Al_2O_3.3SiO_2+K_2O.SiO_2$	S Leucite	5.5–6	2.4–2.5	Tess.
$FeAs_2$	S Leucopyrite	5–5.5	7.0–7.4	Rhomb.
$Fe_2O_3.SiO_2+3(2RO.SiO_2)+H_2O$	S Lievrite	5.5–6	3.9–4.2	Rhomb.
$FeO.Fe_2O_3$	S Magnettite	5.5–6.5	4.9–5.2	Tess.
$(CuO.H_2O+CuO,CO_2)$	S Malachite	3.5–4	3.6–4.0	Monoclin.
$FeO.SO_3+7H_2O$	S Melanterite	2	1.8–1.9	Monoclin.
$3(3PbO.As_2O_5)+PbCl_2$	S Mimetesite	3.5–4.0	7.19–7.25	Hexag.
FeS_2+FeAs_2	S Mispickel	5.5–6.0	6.0–6.2	Rhomb.
MoS	S Molybdenite	1–1.5	4.6–4.9	Hexag.
$Al_2O_3.SiO_2+K_2O.SiO_2$	I Muscovite	2–3	2.8–3.1	Rhomb.
$Al_2O_3.2SiO_2.Na_2O.SiO_2.2H_2O$	S Natrolite	5–5.5	2.17–2.26	Rhomb.
$Na_2O.CO_2+10H_2O$	S Natron	1–1.5	1.4–1.5	Monoclin.
$Al_2O_3.2SiO_2+RO.SiO_2$	S Nepheline	5.5–6	2.58–2.64	Hexag.

Glossary of the Most Important Minerals—Continued.

I=insoluble in or unaffected by acids; S=soluble in or decomposed by acids.

Formula.		Name.	Hardness.	Specific Gravity.	Crystalline System.
$K_2O.N_2O_5$	S	Nitre	2	1.9–2 0	Rhomb.
$Al_2O_3,MgO,K_2O,Na_2O,SiO_2$,&c.	I	Obsidian	6–7	2.2–2.6	Irreg.
$2(Al_2O_3.3SiO_2)+2(Na_2O.CaO).3SiO_2$	I	Oligoclase	6	2.64–2 68	Triclin.
$4CuO.As_2O_5+H_2O$	S	Olivenite	3	4.1–4.6	Rhomb.
$SiO_2.3H_2O$	I	Opal	5.5–6.5	2–2.2	Irreg.
$Al_2O_3.3SiO_2+K_2O.3SiO_2$	I	Orthoclase	6	2.53–2.58	Monoclin.
$Al_2O_3,(Ca.Fe.Mg.Na_2)O,Fe_2O_3,SiO_2$,&c.	I	Pitchstone	5.5–6.0	2.2–2.3	Irreg.
$Al_2O_3.SiO_2+2(CaO.SiO_2)+H_2O$	S	Prehnite	6–7	2.8–3.0	Rhomb.
$3Ag_2S.As_2S_3$	S	Proustite		5.5–5.6	Rhombo.
$Al_2O_3,MgO,K_2O,Na_2O,SiO_2$,&c.	I	Pumice	5	2.2	Irreg.
FeS_2	S	Pyrites	6–6.5	4.9–5.2	Tess.
$3(3PbO.P_2O_5)+PbCl_2$	S	Pyromorphite	3.5–4.0	6.9–7.0	Hexag.
$5FeS.Fe_2S_3$	S	Pyrrhotine	3.5–4.5	4.5–4.6	Hexag.
SiO_2	I	Quartz	7	2.5–2.8	Hexag.
AsS	S	Realgar	1.5–2	3.4–3.6	Monoclin.
TiO_2	I	Rutile	6–6.5	4.2–4.3	Tetrag.
NH_4Cl	S	Sal-ammoniac	1.5–2	1.5–1.6	Tess.
$B_2O_3+3H_2O$	S	Sassoline	1	1.4–1.5	Triclin.
$CaO.WO_3$	S	Scheelite	4–4.5	5.9–6.2	Tetrag.
$Al_2O_3.2SiO_2+CaO.SiO_2+3H_2O$	S	Scolezite	5–5.5	2.2–2.3	Monoclin.
$3MgO.2SiO_2+2H_2O$	S	Serpentine	3–3.5	2.5–2.7	
$FeO.CO_2$	S	Siderite	3.5–4.5	3.7–3.9	Hex., Rhombo.
$CoAs_2$	S	Smaltine	5.5	6.4–7.3	Tess.
$ZnO.CO_2$	S	Smithsonite	5	3.3–3.5	Rhomb.
ZnS	S	Sphalerite	3.5–4	3.9–4.2	Tess. & Tetra.

GLOSSARY OF THE MOST IMPORTANT MINERALS—Concluded.

I=insoluble in or unaffected by acids; S=soluble in or decomposed by acids.

Formula.	Name.	Hardness.	Specific Gravity.	Crystalline System.
$CaO.2SiO_2+CaO.2TiO_2$	S Sphene	5–5.5	3.4–3.6	Monoclin.
$MgO.Al_2O_3$	I Spinel	6	3.4–4.1	Tess.
$(Al.Fe)_2O_3.SiO_2+(Fe.Mg)O.SiO_2$	S Staurolite	7	3.5–3.8	Rhomb.
$Al_2O_3.3SiO_2+CaO.3SiO_2+6H_2O$	S Stilbite	3.5–4	2.1–2.2	Rhomb.
$SrO.CO_2$	S Strontianite	3.5	3.6–3.8	Rhomb.
S	S Sulphur	1.5–2.5	1.9–2.1	Rhomb.
$3(MgO.SiO_2)+HO.SiO_2$	I Talc	1	2.6–2.8	Rhomb. or Monocl.
$4(Cu_2.Ag.Fe,Zn,Hg)S.Sb_2S_3$	S Tetrahedrite	3–4	4.5–5.2	Tess. & Tetrahad.
$Na_2O.SO_3$	S Thenardite	2.5	2.6–2.7	Rhomb.
$RAl_2S_2O_8+5H_2O$	S Thomsonite	5–5.5	2.3–2.4	Rhomb.
$5(Al_2O_3.SiO_2)+Al_2F_6.SiF_4$	I Topaz	8	3.4–3.6	Rhomb.
$B_2O_3, MgO, CaO, (Na.K)_2O, SiO_2$, &c.	I Tourmaline	6.5–7.5	3–3.3	Rhombo.
$3FeO.P_2O_5+8H_2O$	S Vivianite	2	2.6–2.7	Monoclin
$Mn(Ca.Ba.K_2)O.Mn_2O_3+3H_2O$	S Wad	3	2.3–3.7	Irreg.
$3Al_2O_3.2P_2O_5+12H_2O$	S Wavellite	3.5–4	2.3–2.5	Rhomb.
$BaO.CO_2$	S Witherite	3–3.5	4.2–4.3	Rhomb.
$FeO,MnO.WO_3$	S Wolfram	5–5.5	7.1–7.5	Monoclin.

LITHOLOGICAL GEOLOGY.

CHARACTERISTICS OF ROCKS—STRUCTURE.

1. MASSIVE—Like sandstone or granite: breaking one way as easily as another.

2. LAMINATED OR SCHISTOSE—Breaking into scales and slabs like paving stone. Schistose is usually restricted to the crystalline rocks like gness and mica schist.

3. SLATY.—Breaking into thin and uneven plates, like roofing slate.

4. SHALY—Breaking unevenly into fragile plates, like the slate or shale of the coal period.

5. CONCRETIONARY—Having the form of, or containing spherioidal concretions.

6. GLOBULIFEROUS—Having isolated globular concretions, evenly distributed through the texture of a rock.

7. OOLITE—An aggregation of minute concretions in a rock, similar to the eggs or roe of a fish.

FIRMNESS.

1. FLINTY—Very hard and breaking with a smooth surface.

2. COMPACT—Well consolidated.

3. UNCOMPACTED—Like loose earth.

4. POROUS—So loose or open in texture as to absorb water and air readily.

5. FRIABLE—Crumbling in the fingers.

CONSTITUENTS.

1. SILICEOUS—Consisting mainly of quartz.

2. QUARTZOSE—Containing much quartz.

3. QUARTZYTIC—Consisting in part of quartzytic rocks, as quartzite, gneiss, etc.

4. GRANITIC—Like granite (quartz, feldspar and mica.

5. MICACEOUS—Characterized by the greater proportion of mica.

6. FELDSPATHIC—Characterized by the greater proportion of feldspar.

7. ARGILLACEOUS—As clay, or of a clayey nature, as shale, etc.

8. ARENACEOUS—Feebly coherent grains of quartz in any rock.

9. CALCAREOUS—As a mica schist containing carbonate of lime, or any rock similar to a limestone.

10. FERRUGINOUS—Of a red, brown, or yellow color due to the presence of the peroxide of iron in scales or strains through the rock.

11. PYRITIFEROUS—Containing crystals, grains, or masses, of pyrites, disseminated through the rock.

12. PUMICEOUS—Like pumice, of a vesicular nature.

13. GARNETIFEROUS—Containing garnets, as garnetiferous mica-schist.

14. BASALTIC—Like basalt (an igneous rock), made of material derived from basalt.

15. HORNLENDIC—Containing hornblend in greater proportion.

16. HOMOGENEOUS—Having the mineral ingredients not separately distinguishable, but forming a homogeneous mass, granular or otherwise, like slate, and shale, etc.

17. AMYGDALOIDAL—Having numerous almond-shaped cavities filled with crystals and minerals of a nature foreign to the rock, as calcite quartz, and the zedites.

18. SCORIACEOUS — Slag like; very open inflated cells; slag of a furnace, scoria of a volcano.

19. GRANITOID—Relating to granite.

20. GRANULAR—Of a fine or coarse crystalline nature.

21. PHANEROCRYSTALLINE—Distinctly crystalline: as in granite and architectural marble.

22. CRYPTOCRYSTALLINE — Concealed crystalline, as in fine statutary marble.

23. PORPHYITIC—Having the feldspar hornblend, or Pyroxene, in distinct and sometimes twin shaped crystals, disseminated through the rock mass, speckling it all through.

24. DOLOMITIC—Pertaining to the marbles, fine limestone.

25. CALCITIC—Pertaining to or like chalk.

26. DOLERITIC—Like dolerite a feldspathic augite; trap rock.

27. TRAPPITIC—Like any of the true igneous rocks; as trap, basalt and etc.

28. VOLCANIC—Like any of the true volcanic rocks; as lava, obsidian, etc.

29. GNEISSIC—Pertaining to the mica of the rock in laminated planes or layers, as in gneiss.

30. SYENITIC—Like a hornblendic granite or syenite.

31. DIORITIC—Like diorite; a feldspathic hornblend; Trap rock.

32. AUGITIC—Like augite; a black or dark green rock composed of short crystals of pyroxene.

33. FELDSITIC—Pertaining to Felspar; kaolin; porcelain clay.

34. TRACHYTIC—Like trachyte; a light colored, rough feldspathic rock, having small crystals of feldspar.

35. COPROLITIC—Like "fossil excrements," some-

times found in phosphate of lime as phosphatic nodules.

36. CHLORITIC—Like the green stones; pertaining to the chlorine they contain.

METALLIC ORES COMMON IN ROCKS.

1. PYRITE—Often occurs in cubes, a compound of sulphur and iron ($53.^{s}3$:$46.^{fe}7$), pale brass yellow color, less yellow than copper pyrites, strikes fire with steel.

2. PYRRHOTITE—An iron pyrites; (40^{s}:60^{fe}) is as soft as copper pyrites, but of a pale bronze color.

3. CHALCOPYRITE — Copper pyrites; an easily scratched, deep yellow compound of s. fe. and cu. easily crushed into a dark green powder.

4. GALENITE—Galena, most common ore of lead (13.4^{s}—86.6^{Pu}.) occurs in cubes of a soft, brittle, lead-gray color, also in dodecahedrons and other forms.

5. SPHALERITE—Zinc blend, ($33.^{s}$ $67^{zn.}$) a black, brown, or resin yellow crystalline mass, yielding a whitish powder.

6. HEMATITE—Bog iron ore, specular iron ore (fe^{2} o^{3}) in steel gray crystals and masses and deep red earthy masses, giving a red powder.

7. MAGNETITE—Magnetic iron ore ($fe^{3}o^{4}$) in massive iron gray crystals yielding a black powder.

8. LIMONITE—Hydrous iron ore (2 $fe^{2}o^{3}$-|-3 $H^{2}o$); black and brown yellow earthy masses yielding a brown yellow powder.

9. MENACCANITE—Titanic iron ore similar in composition to Hematite but containing Fitanium black crystals yielding a black powder.

10. GRAPHITE—Plumbago, black lead (the material of lead pencils) and amorphous, shining mass of pure microscopical carbon crystals.

MATERIALS OF ORGANIC ORIGIN.

1. Siliceous—The spicula, teeth, shields, and shells of the siliceous sponges, mollusks, diatomes, and polycystines which have contributed to the silica of the rocks, and may have originated the flints.

2. Calcareous—The shells of the crinoids, corals, corallines, etc., which have contributed to the formation of phosphate of lime and fluoride.

3. PHOSPHATIC—The bones, excrements, animal tissues, shells of crustaceans and of animals, edible grains, fruits, etc., and the guano of birds and bats.

4. CARBONACEOUS—The plants, which have afforded mineral oil, coal, and resin.

5. ORGANIC TISSUES—The flesh of animals sometimes fossil found imbedded in the mud, composing the rock forming phosphates and fluorides of lime.

(Dana's Manual and my own notes.)

For those who wish to obtain only a fair knowledge of the more common minerals and metal-bearing rock, I have here introduced from J. D. Dana his series of colors, lustre, scale of hardness, taste and odor, after which we will insert the name and number in series, also the names of the different minerals, and proceed to determine a mineral by that method.

DIAPHANEITY, LUSTRE, COLOR.

Diaphaneity.

"Diaphaneity is the property which many objects possess of transmitting light; or, in other words, of permitting more or less light to pass through them. This property is often called transparency, but transparency is properly one of the degrees of diaphaneity. The following terms are used to express the different degrees of this property:

"Transparent—when the outlines of the objects, viewed through the mineral, are distinct. Example: glass, crystals of quartz.

"Subtransparent, or semi-transparent—when objects are seen but their outlines are indistinct.

"Translucent—when merely the edges transmit light faintly.

"When no light is transmitted the mineral is described as opaque.

"LUSTRE.

"The lustre of minerals depends on the nature of their surfaces, which causes more or less light to be reflected. There are different kinds of intensity of lustre, and also different kinds of lustre.

"a. The kinds of lustre are six, and are named from some familiar objects or class of objects.

"1. Metallic—The usual lustre of metals. Imperfect metallic lustre is expressed by the term submetallic.

"2. Vitreous—The lustre of broken glass. An imperfect vitreous lustre is termed subvitreous. Both the vitreous and subvitreous lustres are common. Quartz possesses the former in an eminent degree; calcite often the latter. This kind of lustre may be exhibited by minerals of any color.

"3. Resinous——Lustre of the yellow resins. Example: some opal, zinc blende.

"4. Pearly—Like pearl. Example: talc, native, magnesia, stilbite, etc. When united with submetallic lustre the term metallic-pearly is applied.

"5. Greasy—Looking as if smeared with oil. Example: elaeolite, some quartz.

"6. Silky—Like silk; it is the result of a fibrous structure. Example: fibrous calcite, fibrous gypsum, and many fibrous minerals, more especially those which in other forms have a pearly lustre.

"7. Adamantine—The lustre of the diamond. When submtallic, it is termed metallic adamantine. Example: some varieties of white lead-ore or cerussite.

"b. The degrees of intensity are denominated as follows:

"1. Splendent—When the surface reflects light with great brilliancy and gives well-defined images. Example: crystals of henatite, cassiterite, some specimens of quarts and pyrite.

"2. Shining—When an image is produced, but not a well-defined imagke. Example: calcite, celestite.

"3. Glistening—When there is a general reflection from the surface, but no image. Example: talc.

"4. Glimmering—When the reflection is very imperfect, and apparently from points scattered over the surface. Example: flint, chalcedony.

"A mineral is said to be dull when there is a total absence of lustre. Example: chalk.

COLOR.

"1. Kinds of Color.—In distinguishing minerals, both the external color and the color of a surface that has been rubbed or scratched, are observed. The latter is called the streak, and the powder abraded, the streak-powder.

"The colors are either metallic or unmetallic.

"The metallic are named after some familiar metal, as copper-red, bronze-yellow, brass-yellow, gold-yellow, steel-gray, lead-gray, iron-gray.

"The unmetallic colors used in characterizing minerals are various shades of white, gray, black, blue, green, yellow, red and brown.

"There are thus snow-white, reddish-white, greenish-white, milk-white, yellowish-white.

"Bluish-gray, smoke-gray, greenish-gray, pearl-gray, ash-gray.

"Velvet-black, greenish-black, bluish-black, grayish-black.

"Azure-blue, violet-blue, sky-blue, indigo-blue.

"Emerald-green, olive-green, oil-green, grass-green, apple-green, blackish-green, pistachio-green (yellowish).

"Sulphur-yellow, straw-yellow, wax-yellow, ochre-yellow, honey-yellow, orange-yellow.

"Scarlet-red, blood-red, flesh-red, brick-red, hyacinth-red, rose-red, cherry-red.

"Hair-brown, reddish-brown, chestnut-brown, yellowish-brown, pinchbeck-brown, wood-brown.

"A play of colors: This expression is used when several prismatic colors appear in rapid succession on turning the

mineral. The diamond is a striking example; also precious opal.

"Change of Colors—When the colors change slowly on turning in different positions, as in labradorite.

"Opalescence—When there is a milky or pearly reflection from the interior of a specimen, as in some opals, and in cat's-eye.

"Iridescence—When prismatic colors are seen within a crystal; it is the effect of fracture, and is common in quartz.

"Tarnish—When the surface colors differ from the interior; it is the result of exposure. The tarnish is described as irised when it has the hues of the rainbow."

TASTE.

Taste belongs only to the soluble minerals. The kinds are:

"1. Astringent—The taste of vitriol.
"2. Sweetish-astringent—The taste of alum.
"3. Saline—Taste of common salt.
"4. Alkaline—Taste of soda.
"5. Cooling—Taste of saltpetre.
"6. Bitter—Taste of Epsom salts.
"7. Sour—Taste of sulphuric acid.

"Odor is not given off by minerals in the dry, unchanged state, except in the case of a few gases and soluble minerals. By friction, moistening with the breath, the action of acids, and the blowpipe, odors are sometimes obtained which are thus designated:

"1. Alliaceous—The odor of garlic. It is the odor of burning arsenic, and is obtained by friction, and more distinctly by means of the blowpipe, from several arsenical ores.

"2. Horse-radish Odor—The odor of decaying horse-radish. It is the odor of burning selenium, and is strongly

perceived when ores of this metal are heated before the blowpipe.

"3. Sulphureous—Odor of burning sulphur. Friction will elecit this odor from pyrites, and heat from many sulphides.

"4. Fetid—The odor of rotten eggs or sulphuretted hydrogen. It is elicited by friction from some varieties of quartz and limestone.

"5. Argillaceous—The odor of moistened clay. It is given off by serpentine and some allied minerals when breathed upon. Others, as pyrargillite, afford it when heated."

To discover the hardness of a mineral, it is necessary to find out which of the typical specimens of the scale of hardness is scratched by it.

1. Talc (such as soapstone), easily scratched by the finger nail.

2. Rock salt (also gypsum, zinc, etc.), not easily scratched by the nail, nor can they scratch a copper coin.

3. Calc spar (transparent), both scratches, and can be scratched by a copper coin.

4. Fluor spar, not scratched by a copper coin, and does not scratch glass.

5. Apatite, with difficulty scratches glass, and is easily scratched by a knife.

6. Feldspar, scratches glass, and is not easily scratched by a knife.

7. Quartz, not scratched by a knife and easily scratches glass.

8. Topaz, harder than flint.

9. Corundum is emerald.

10. Diamond, which scratches everything.

SPECIFIC GRAVITY OF MINERALS.

1.	Asphaltum	1.	1.8
2.	Graphite	2.	
3.	Brucite	2.	3.5
4.	Orthoclase	2.5	2.6
5.	Quartz	2.	6.
6.	Calcite	2.	72.
7.	Apatite	2.9	3.2
8.	Pyroxine	3.2	3.3
9.	Titanite	3.15	
10.	Garnet	3.15	4.3
11.	Fluorite	4.	
12.	Sphalerite	3.9	42.
13.	Perofskite	4.03	41.
14.	Brookite	4.03	41.
15.	Rutile	4.2	
16.	Barite	4.5	
17.	Pyrite	4.9	
18.	Magnetite	4.9	52.
19.	Antimony	6.2	
20.	Cassiterite	6.4	7.1
21.	Galena	7.5	
22.	Copper	8.9	
23.	Mercury	13.	5.
24.	Platinum	16.	19.
25.	Iridosmine	19.3	21.

SCALE OF COLOR.

White.

1. Snow-white..... Aragonite.
2. Tin-white..... Antimony.

Gray.

3. Pearl-gray..... Talc.
4. Ash-gray..... Zoisite.
5. Pure lead-gray..... Galena.

Black.

6. Velvet-black..... Tourmaline.
7. Brownish-black..... Cannel coal.
8. Iron-black..... Franklinite.

Blue.

9. Azure-blue..... Azurite.
10. Violet-blue..... Fluorite.
11. Indigo-blue..... Vivianite.

Green.

12. Verdigris-green..... Garnierite.
13. Emerald-green..... Emerald.
14. Olive-green..... Olivine.

Yellow.

15. Sulphur-yellow..... Sulphur.
16. Honey-yellow..... Copalite.
17. Orange-yellow..... Wulfenite.
18. Dark brass yellow..... Chalcopyrite.

Red.

19. Blood-red..... Zincite.
20. Carmine-red..... Chalcotrichite.
21. Rose-red..... Rose quartz.
22. Copper-red..... Copper.

Brown.

23. Reddish-brown..... Jasper.
24. Hair-brown..... Titanite.
25. Yellowish-brown..... Opalized wood.

The proper way is first to construct the following blank and note in each place the physical properties and chemical reactions of all the tests made, then consult Dana under each heading of color, hardness, lustre, fracture, touch, taste, cleavage, odor, specific gravity, etc. By this means you will soon learn how to classify all the more common ores and minerals.

MINERAL ANALYSIS.

Work Patiently; Observe Every Characteristic and Change Carefully.

PHYSICAL PROPERTIES.

Form..... Structure.....
Color..... Streak.....
Lustre—Kind..... Transparency.....
Degree.....
Hardness..... Tenacity.....
Fracture..... Cleavage.....
Touch..... Odor.....
Taste..... Sp. Gr.,.....
Rare Props.....

CHEMICAL REACTIONS.

Solubility..... Fusibility.....
Fl., Color..... Reaction.....
Closed Tube..... Open Tube.....
On Ch.,..... Sol. Cobalt.....
With soda on ch.,..... Sulphur test.....
Borax bead—O. F.....Hot .....Cold
R. F.....Hot .....Cold
Phos. bead—O. F.....Hot .....Cold
R. F.....Hot .....Cold
Remarks .....
.....
NAME..... Composition.....
Locality..... Date.....

To Ascertain the Characteristics of Any Species.—Look in the list for the species number, and by this the species can be found in its order in the "Table of Species."

To Determine Any Mineral.—Test the hardness with a file, or, better with the minerals in the scale of hardness. It will be found in one of the columns of the "Table of Hardness." Then, determining the color, we look in the column of this color in the "Table of Color" and find that there are only a few of the numbers of the previously ascertained hardness in this column; then, determining the crystalline form or specific gravity, we eliminate others, bringing it finally down to one or two, which we find in their order in the "Table of Species," and compare their qualities. Take Cuprite as an example. We easily find that its hardness is 3.5 to 4. It must be in the column headed 3.5 to 4, or 4 to 4.5. Its color is cochineal red. Its crystallization is 1, streak 77-71. Cuprite is the only one agreeing

with these readily recognized characteristics. As another common mineral, take green fluorspar in cubes. Its hardness is 4, its color 4, its crystallization 1. Its cleavage is B. octohedral; 159 is the only mineral combining these qualities.

One will be assisted in forming an opinion as to the probable identity of the mineral under consideration by remembeing that in each column of the numerical tables the most common minerals form the first-third of each class.

Again we will examine a mineral which is quite common in Oregon. Uraninite (uranium oxide) is the ore usually found by prospectors and generally occurs in connection with lead and silver ores, very rarely in masses. The crystals are octahedrons. The color may be gray, brown, or velvet black, and sometimes has a lemon yellow coating of uraconite. It is rarely found as a pure ore. The hardness is six and the gravity ten, being softer than quartz, which is seven, and heavier than galena, which is 7.25. It will scratch about as easily as ordinary feldspar, which is six to seven. It is hard, but slightly malleable. With the oxidizing flame of an ordinary blowpipe an equal amount of the ore and borax will give a red scoriae when hot and yellow or gray when cold. Reduced to a powder it will dissolve very slowly in nitric acid. The streak or powder formed by scratching with file or point of knife is black. It has but little lustre, being dull or sub-metallic. Uraninite (uranium oxide) is the only one which answers this description.

BLOWPIPE ANALYSIS.

The following method has been devised and arranged by J. S. Phillips, M. E., for the beginner, that he may be enabled to distinguish the useful minerals without puzzling over chapters of complicated reading matter and reactions in qualitative analysis, which can be understood only after a long course of study and much practice.

However, he should be acquainted with the blowpipe, and know the difference between the oxidizing and the reducing flame; the discrimination on charcoal; the platinum wire loop, and the use of glass tubes, open or closed, over a spirit lamp.

Before commencing the tests write these names:

Antimony,	Chromium,	Lead,	Sulphur,
Arsenic,	Cobalt,	Manganese,	Tellurium,
Bismuth,	Copper,	Mercury	Tin,
Chlorine,	Iron,	Nickel,	Zinc.

With the manganese, quartoze, and lime rocks, and then proceed as follows: Prepare some finely pulverized borax and some phosphate of soda, and, having first brought the platinum wire loop to a red heat, touch it to the pulverized borax, and again hold it in the flame until it is melted and forms a transparent borax bead; touch it to the ore to be tested and a glass will be formed.

Carbonate or phosphate of soda is to be fused in the same manner until the bead is formed on the platinum wire, and then testing the ore as above described.

"Thoroughly fuse some of the finely pulverized ore with carbonate of soda, within the small terminal eye or loop of

platinum wire, in the oxidizing flame; and notice the color of the glass.

"If the glass is pale yellow? Chromic acid is present, from some chromate ore.

"If the glass is of a bluish green? It has been produced by manganese.

"If of a copper red? From copper reduced by this flux.

"If of a lead colored enamel? From reduced lead.

"If not thus colored, erase chromium and manganese from your list and test for the remainder.

"Fuse in similar manner with borax.

"If the glass is blue? The mineral is cobalt

"If amethyst? Manganese. (But this would not be present if the carbonate of soda failed to show it.)

"If of a reddish brown? Nickel.

"If neither color? Expunge cobalt, iron, and nickel from the list.

"Place a small piece of the mineral, of about the size of a grain of wheat, upon unfluxed willow or pine charcoal, and subject it to the oxidizing flame of the blowpipe, until an intense heat is produced, which continue for about one minute, (and when cold it may be applied to the magnetic needle, as a collateral test for iron.)

"If there is no white, or yellow oxide, deposited on the coal, the specimen does not contain antimony, arsenic, bismuth, lead, tin, tellurium, or zinc, and those may be also erased from the list.

"If you wish to examine for the rocks, do so now.

"Quartz scratches glass, before and after strong ignition.

"Lime would now dissolve, or slack, in water.

"Magnesia and alumina, when moistened with a drop of the 'solution of cobalt' and again strongly heated, will respectively show their characteristic flesh, or blue colors.

"If a white oxide deposits on the charcoal, at some dis-

tance from the test sample, it will be from antimony, arsenic, or tellurium.

"Antimony has a pleasant, flower-like odor; arsenic, a disagreeable garlic stink; and the oxide of tellurium will burn off with a green flame, before that from the blowpipe.

"If the oxide on the charcoal is white, and close to the test sample, it is produced from tin.

"If the oxide is yellow when hot, and white when cold, it is that of zinc.

"The oxide of tin, when moistened with 'solution of cobalt,' and re-heated before the blowpipe, becomes of a greenish blue color; whilst the oxide of zinc, when thus treated, changes to a bright green.

"If the oxide on the charcoal is yellow, it is either from lead or bismuth. Smelt on charcoal with carbonate of soda, and these minerals will thus be reduced to metals. Bismuth is very brittle, and lead very ductile under the hammer.

"You have now thoroughly tested for all but chlorine, copper, mercury and sulphur.

"Copper was alluded to as coloring the first bead of carbonate of soda, but it may now be further tested and more effectually reduced on charcoal, when fluxed with, say, equal parts of soda and sugar, to irregular nuggets of red metal.

"It may also be detected in very small quantities when it has been first roasted in flame, then moistened with hydrochloric acid, and re-flamed; as it first gives the blue flame, from the chlorine of the acid, then finishes with the beautiful green flame of the copper.

"CHLORINE.—Fuse in the platinum wire a bead of microcosmic salt, with as much oxide of copper (or any copper ore thus oxidized) as it will absorb, then add the liquid or solid, that is to be tested, and place it into or before the

flame; if chlorine is present it will soon show its characteristic blue.

"SULPHUR.—Lay the first bead formed with carbonate of soda, or any other of the slags from the smeltings with that flux, on a moistened silver coin, and if the ore is a sulphuret, it will, by forming the soluble sulphate of soda, stain the bright silver, from brown to black, according to the quantity of sulphur present, or time given for the discoloration.

"MERCURY.—Place a small piece of the raw ore on a gold or copper coin, and impinge the flame from the blowpipe thereon, for a few seconds, so that the heated current, beyond the test sample, may pass close down upon the cold coin, when—if it be an ore of mercury—its flame will condense and amalgamate the surface of the metal, which can be more distinctly observed, after the coin has been rubbed with a wet finger. The coin may be again cleaned by warmth.

"Thus, the qualitative analysis of the profitable base minerals may be readily and thoroughly completed, by men knowing nothing of minerals at sight, and the particular metal, or metals, found, may be then assayed for correct quantity, by either of the convenient modes.

"The short abstract statement of operations for testing by the above mode, as given beneath, may be easily remembered.

"1. Test, with carbonate of soda in platinum loop, for colored beads, of chromium, manganese, copper, and lead.

"2. Test, in similar manner with borax, for colored beads, from iron and nickel; and also look for collateral amethyst color, of manganese.

"3. Test, on charcoal, for iron, by the magnetic needle; for the oxides of antimony, arsenic, bismuth, lead, tin, tellurium, and zinc, by their colors, etc., etc.; and for the

rocks, of quartz by hardness, lime by its solubility, and of magnesia and alumina by the flesh and blue colors produced by 'nitrate of cobalt' solution.

"4. Test for copper, by actual reduction, and color of its flame when dissolved in hydrochloric acid; for chlorine, by a copper saturated bead of microcosmic salt, by its blue flame; for sulphur, by fusion with carbonate of soda, and dissolving the mass on a silver coin, by its brown color; and for mercury, by hot blast to the sample when placed on a gold or copper coin, by its amalgamation."

CALCULATION OF LEAD BLAST FURNACE CHARGES.

This is a very complicated matter for some of the charges which work well in one part of the country will not do in another section, owing, probably, to the amount of alumina or zince present which is seldom taken into consideration. Not only must the charge be so calculated as to have a sufficient amount of lead, but that the bullion will be of a proper grade.

Only a few years ago a 20 per cent lead charge was considered necessary in order to make a good slag, but now a 12 per cent charge of lead is considered quite sufficient. It must be regulated by the supply of ore on hand, or what may be expected to arrive. Oftimes the metallurgist is blamed for not making a clean slag when the chemist is really at fault for not properly sampling and analyzing the ore.

TABLE FOR VARIOUS TYPES OF SLAG.

Notation.	SiO Per Cent.	FeO Per Cent.	CaO Per Cent.	ZnO Per Cent.
A.....	34	29	28	..
B.....	34	34	24	..
C.....	34	34	18	6
D.....	30	40	20	..
E.....	30	48	12	..
F.....25 to 30		54	6	..

A is a good slag which is generally used in Utah.

B is also considered most effective; a great favorite in Utah.

C is a Colorado slag, and runs well even with zinc.

D is called a half slag; has been extensively used in Colorado and Utah.:

E is what is known as a quarter slag.

F is only recommended where there is plenty of iron and dry ore is not available.

The weight of fuel to be used will depend upon the character of the charge, the fusibility of the slag, the altitude of the place, the character of the coke or charcoal used, and the dimensions of the furnace.

The coke or coal used is from 12 to 25 per cent of the total weight of the ore taken; some of the sulphur may act as a fuel, which must be taken into consideration. The amount of lead will affect the fuel, a high lead charge requiring less; all these things must be considered by the metallurgist, and he be given time to practice on his charge, but invariably when a metallurgist is employed by inexperienced men to run a furnace, if by any cause there is a failure to come up to the requirement, he is discharged and another employed to do the same thing.

WORKING TEST OF GOLD OR SILVER ORES.

Many times the prospector desires to make a working test of his ore, that he may know the probable results by mill process. This can readily be done by finely pulverizing a few pounds of the ore, and, if free from all sulphurets testing it at once by amalgamation.

But if the ore is a sulphuret it must first be roasted with charcoal and carbonate of ammonia and the ore completely oxidized before any amalgamation can be had.

If the ore is a sulphuret of silver in any form it may be chloridized by roasting it with salt until the ore has a reddish appearance of iron rust when cold. The chloridizing of a small lot can be done in the muffle, or if of several pounds an old box stove can be made to answer as a reverbatory furnace, and the ore constantly stirred during chloridization. When sufficiently roasted and it has no smell of sulphur it may be withdrawn from the fire and cooled, then placed in a leaching cloth in a large funnel and over it poured a strong hot solution of common salt, or a cold solution of hypo-sulphite of soda, which will leach out all the chloride of silver into a receiving vessel when it can be at once precipitated with a solution of polysulphide of sodium and collected on a filter and smelted into a button of lead and cupelled.

But if the ore is a gold sulphuret ore it can only be roasted with charcoal and carbonate of ammonia, until no further smell of sulphur is noticed.

Then weigh out from one to five pounds as desired, and treat about a half pound at a time, which will be sufficient for an ordinary Buck's grinder; add hot water just so it will

be the consistency of mud; sift in a little quicksilver through a buckskin and add one or two pennyweights of sodia amalgam, and grind for 15 or 20 minutes, then wash out the mortar into a pan, and continue until all the pulp is worked up, when it may be vanned down to an ounce or so, the quicksilver collected and strained through buckskin, the amalgam retorted on a shovel, and the gold weighed and calculated per ton.

It is frequently the case that there will be more or less globules of foul quicksilver left after vanning; in such a case it is best to dry the vannings, including the amalgam, and assay it in the usual way for free-milling ore and from the resulting bead calculate results.

Many think that by milling and working 500 or 1,000 pounds of ore by mill will give them accurate milling results, but this is a mistake, for any one who knows anything about milling gold rock, knows that there is always a loss in cleaning up a mill, and this loss is as much from cleaning up a 2,000-pound run as it would be on a run of ten tons. Suppose we mill one ton of 2,000 pounds of 20-dollar rock and the loss in cleaning up the mill is $5.00, the loss is 25 per cent, leaving only $15.00 per ton as a working test. Suppose we mill ten tons, the loss is no more than $5.00 on the whole lot, which is only $2\frac{1}{2}$ per cent against 25 per cent on the one ton.

It is much better to select 30 or 40 good average samples from a mine and take them to a good, reliable assayer who is equipped with a first-class balance and take his results as an average, then throw off 15 per cent for milling, and the result will be far more satisfactory than any milling test unless you mill ten tons or more.

ASSAYING SOLUTIONS.

Many times it is necessary for us to determine the amount of gold in a given quantity of solution, either in cyanide or chloride solution. To do this, take some sheet lead c. p., lay upon it a square block of wood about $2\frac{1}{2}$ inches square, and you have a convenient measure to cut your lead, the block acting as a guide for your knife to form a square piece of lead. Now make another block of about $1\frac{1}{4}$ inches square, over this fold the peice of sheet lead, pressing the corners together in the form of a triangle. If a little care is exercised in bringing the corners together evenly, the tray when completed, will be of nearly equal height on all sides and hold fluid full to the brim. You now have a square tray. A very convenient quantity of the solution to evaporate down is two assay tons. Take a 50 c.c. graduate and fill with two assay tons of solution, pour it carefully into the lead tray, and evaporate it down on a stove or over any convenient flame, boiling lively. Add silver if you wish to ascertain gold alone, and cupel, part the button obtained and weigh. If fifty divisions on the beam of your assay balance corresponds with one milligram weight in the pan, then each division on the beam will mean one one-hundredth of a milligram for your gold button. The advantage of using two assay tons of the solution then, is that in weighing no calculation is necessary. You have simply to register the actual reading of the beam.

ORE IN SIGHT.

"ORE IN SIGHT," may be defined as that contained in blocked portions of the deposit, each of which is so clearly exposed by sections on several sides between the levels run, that the limits, continuity and value of its contents may be determined and relied upon with reasonable certainty. Such are so exposed, may be considered a proved resource, ready for extraction and susceptible of expression in terms of net profit.

EXTRACTING COPPER BY CHLORIDIZING.

Sulphurets of copper ores can be profitably worked by breaking the ore up into small pieces the size of a hen's egg, and piling alternately in layers of wood and burning for several days. This volatilizes sufficient sulphur to render the rock more friable for crushing and pulverizing in any iron mill.

The finely pulverized ore is now subjected to a chloridizing, roasting with sufficient salt to change all the copper to a chloride, which requires some fifteen minutes after the proper temperature has been reached under continued stirring.

The roasted charge is now placed in vats and the chloride of copper is dissolved out with hot water, filtered into. or allowed to settle and run into another tank or vessel, and precipitated with metallic iron or with caustic lime water; it is then dried and pressed into cakes and is ready for the smelter.

ESTIMATING PERCENTAGE OF SULPHURETS IN QUARTZ.

To estimate the amount of sulphurets in quartz, take 10,000 grains or 20.8 ounces troy of crushed rock, so that it will pass through a 40-mesh screen. Pan it down very carefully in a gold pan or other dish. Dry and weigh. Each grain of sulphurets will equal one-hundredth of 1 per cent.

Suppose the sulphurets weighed only 40 grains, then the ore contained only 2-5 of one per cent per ton; if the ore contained 5 grains of sulphurets there would be one per cent of the sulphurets. Suppose 500 grains of sulphurets, then we would have 5 per cent of sulphurets per ton, or if 750 grains of sulphurets, then $7\frac{1}{2}$ per cent per ton, etc.

If the sulphurets were worth $100 per ton the value of sulphurets in each ton would be—for the 2-5, $ .40 per ton. If we obtained 5 grains it would be $1.00 per ton. If we obtained 500 grains the value would be $5.00 per ton, etc. Of course if the ore is richer the values will be increased in that proportion.

USEFUL DATA.

TO MAKE SILVER AMALGAM.

Silver amalgam is better to use on copper plates than quicksilver alone, and a little soda amalgam may be used in the battery with it, occasionally.

To make silver amalgam take three parts of pure silver rolled thin and drop it into one part of quicksilver; one-fourth of an ounce of this amalgam will cover each square foot of surface to be amalgamated, and should be well rubbed in.

If pure silver cannot be had it can be made from silver coin by dissolving in dilute nitric acid in a porcelain dish and evaporating to dryness over a water bath. Heat the dry mass gently until it fuses and all the bluish tint has changed to grayish black, which shows that the copper alloy in the coin has become an insoluble oxide. Then dissolve the mass in as little water as possible and filter into a glass jar, adding the quicksilver required, then dropping in some bright strips of sheet iron; the silver will deposit as metallic silver and form an amalgam with the quicksilver. Let it stand two or three days and the silver will all be deposited and the amalgam formed ready for use.

To reduce grammes to grains, multiply by 15.432.

To reduce grains to grammes, multiply by .0648.

To reduce ounces to grammes, multiply by 28.349.

To convert degrees of centigrade thermometer to Fahrenheit, multiply by 9, divide by 5, then add 32.

To convert degrees of Farenheit thermometer to centigrade, first subtract 32, then multiply by 5, and divide by 9.

To determine the specific gravity of minerals or other

substances, weigh in air, then in water, and divide the weight in air by the difference.

"The average fineness of gold in Oregon is 875.5.

1 grain of pure gold is worth.....	$ 0.0430663
1 gramme of pure gold is worth.....	0.6646×
1 ounce Troy of pure gold is worth.....	20.671791
1 pound, average, of pure gold is worth...	301.46×
1 ton (2000 lbs. = 29166.6 oz. Troy).....	602927.36
1 cubic inch (10.12883 oz. Troy).....	209.38
1 cubic foot (17502.62 oz. Troy).....	361808.64

The heaviest substance known is the metal osmium, whose specific gravity is 22.477, while that of gold is $19.265, lead 11.367, iron 7.79, and lithium—the lightest solid—is only 0.594. Osmium is also the most infusible of the metals. It resists the oxyhydrogen flame of 3550° Fahr., in which platinum and iridium flow, and is even almost entirely unaffected by the electric arc, which readily melts the extremely refractory ruthenium. It was discovered by Tennant in 1803, and is found in iridosmine and platinum.

Definition of an Acid.—An acid molecule is one which consists of one or more negative atoms united by oxygen to hydrogen. Recognized by turning certain vegetable blues to red.

Definition of a Base.—A basic molecule consists of one or more positive atoms united by oxygen to hydrogen. Bases restore the color to any vegetable blue which has been reddened by an acid.

The value of gold per oz. is calculated from the basis that 387 oz. of pure gold (1000 fine) is worth $8000. Hence 1 oz. is worth $20.671834625, and the 1-1000 of an oz. (decimally expressed as .001) is worth $0.020671834625.

What we usually call fineness, therefore, is simply the weight of fine metal contained in a given quantity of mixed

metals or alloys. For instance, in a gold or silver bar which is reported to be 850 fine, it is simply meant that in 1000 parts by weight, 850 are fine gold or fine silver, as the case may be.

In our mints, the value of gold is computed from standard weight; that is, gold which is 900 fine, that being the fineness of our gold coin as required by law. The formula in this case is, 43 oz. of standard gold are worth $800. Hence, multiply standard oz. by 800, and divide by 43, and you obtain the value.

Example—Take 126 15-100 oz. at 856 fine, and we obtain the result thus:

126.15 oz.
856 fineness of gold.

---

756 90
6 307 5
100 920

U. S. standard,900) 107,984.40 oz. of fine gold.

119,982 oz. standard gold.
800

---

43) 95,985.600

$2,232.22 value.

To find value per oz., divide total value ($2,232.22) by standard oz. (119,982) and you have $18.60[46], which is the value of 1 oz. of gold at 900 fine.

ASSAY TABLE.

For Twenty Grammes of Ore.

Bead Points.	Ounce in a Ton of the Ore.	Value in Gold (Dollars).
.1	.14583	$ 3.01464
.2	.29166	6.02928
.3	.43750	9.04392
.4	.58333	12.05856
.5	.72916	15.07320
.6	.87500	18.08785
.7	1.02083	21.10249
.8	1.16666	24.11713
.9	1.31250	27.13177
1.	1.45833	30.14642
2.	2.91667	60.29284
3.	4.37500	90.43926
4.	5.83333	120.58567
5.	7.29167	150.73209
6.	8.75000	180.87851
7.	10.20833	211.02493
8.	11.66667	241.17135
9.	13.12500	271.31777

ASSAY TABLE.

For One Assay Ton of Ore.

Ounces.	Gold Value.	Silver Value.
.1.....	$ 2.0678	$ .12929
.2.....	4.1343	.25858
.3.....	6.2015	.38787
.4.....	8.2687	.51717
.5.....	10.3369	.64646
.6.....	12.4301	.77575
.7.....	14.4702	.90505
.8.....	16.5375	1.03434
.9.....	18.6046	1.16363
1.	20.6783	1.29292
2.	41.3436	2.58585
3.	62.0155	3.87878
4.	82.6873	5.17171
5.	103.3591	6.46464
6.	124.0310	7.75757
7.	144.7028	9.05050
8.	144.7028	10.34343
9.	186.0465	11.63636

METRIC, OR FRENCH WEIGHTS.

		Grammes		Troy Grs	Troy Oz
1/10 Milligramme	=	.0001	=		
1 Milligramme	=	.001	=	.01543	
1 Centigramme	=	.01	=	.15432	
1 Decigramme	=	.1	=	1.5432	
1 Gramme	=	1.	=	15.432	.032
1 Decagramme	=	10.	=		.321
1 Hectogramme	=	100.	=		3.215
1 Kilogramme	=	1000.	=		32.150
1 Myriagramme	=	10000.	=		
1 Quintal	=	100000.	=		
1 Tonneau	=	1000000.	=		

TABLE FOR ORE ASSAYS.

For One 1,000,000 of Ten Grains Obtained. From One Ounce Troy, Gives Per 2000 Pounds Average 0, 60, 75 Ounces.

GOLD.

1,000,000th of 10 Grains.	Weight. Ounce.	Dec.	Value.	1,000,000th of 10 Grains.	Weight. Ounce.	Dec.	Value.
.00001	00	006	$ .12	.010	6	07	$ 125.46
.00002	00	012	.24	.011	6	68	138.07
.00004	00	024	.49	.012	7	29	150.68
.00005	00	030	.62	.013	7	89	163.08
.00006	00	036	.74	.014	8	50	175.69
.00007	00	042	.86	.015	9	11	188.30
.00008	00	048	.99	.016	9	72	200.91
.00009	00	054	1.11	.017	10	32	213.31
.0001	00	06	1.24	.018	10	93	225.92
.0002	00	12	2.48	.019	11	54	238.53
.0003	00	18	3.72	.020	12	15	261.54
.0004	00	24	4.96	.021	12	75	263.54
.0005	00	30	6.20	.022	13	36	276.15
.0006	00	36	7.44	.023	13	79	288.76
.0007	00	42	8.68	.025	15	18	313.77
.0008	00	48	9.92	.026	15	79	326.28
.0009	00	54	11.16	.027	16	40	338.98
.001	00	60	12.40	.028	17	01	351.59
.002	1	21	25.01	.029	17	61	363.99
.003	1	82	37.62	.030	18	22	376.60
.004	2	43	50.23	.031	18	83	389.21
.005	3	03	62.63	.032	19	44	401.82
.006	3	64	75.24	.033	20	04	414.22
.007	4	25	187.84	.034	20	65	426.83
.008	4	86	100.45	.035	21	26	439.44
.009	5	46	112.85	.036	21	87	452.03

.037	22	47	$ 464.45	.074	44	95	
.038	23	08	477.06	.075	45	56	
.039	23	68	489.46	.076	46	17	
.040	24	30	502.28	.077	46	77	
.041	24	90	514.68	.078	46	77	
.042	25	51	527.29	.079	47	99	
.043	26	12	539.90	.080	48	60	
.044	26	73	552.30	.081	49	20	
.045	27	33	564.91	.082	49	81	
.046	27	94	577.51	.083	50	42	
.047	28	55	590.12	.084	51	03	
.048	29	16	602.73	.085	51	63	
.049	29	76	615.13	.086	52	24	
.050	30	37	627.74	.087	52	85	
.051	30	98	640.35	.088	53	46	
.052	31	99		.089	54	06	
.053	32	19		.090	54	06	
.054	32	80		.091	55	28	
.055	33	41		.092	55	89	
.056	34	02		.093	56	49	
.057	34	62		.094	57	10	
.057	35	23		.095	57	71	
.059	35	84		.096	58	32	
.060	36	45		.097	58	92	
.061	37	05		.098	59	53	
.062	37	66		.099	60	14	
.064	38	88		.100	60	75	$1255.70
.065	39	48		.200	121	50	
.066	40	09		.400	243	00	
.067	40	70		.500	303	75	
.068	41	31		.600	364	50	
.069	41	91		.700	425	25	
.070	42	52		.800	486	00	
.071	43	13		.900	546	75	
.072	43	74		1.000	607	50	
.073	44	34					

TABLE FOR WEIR MEASUREMENT.

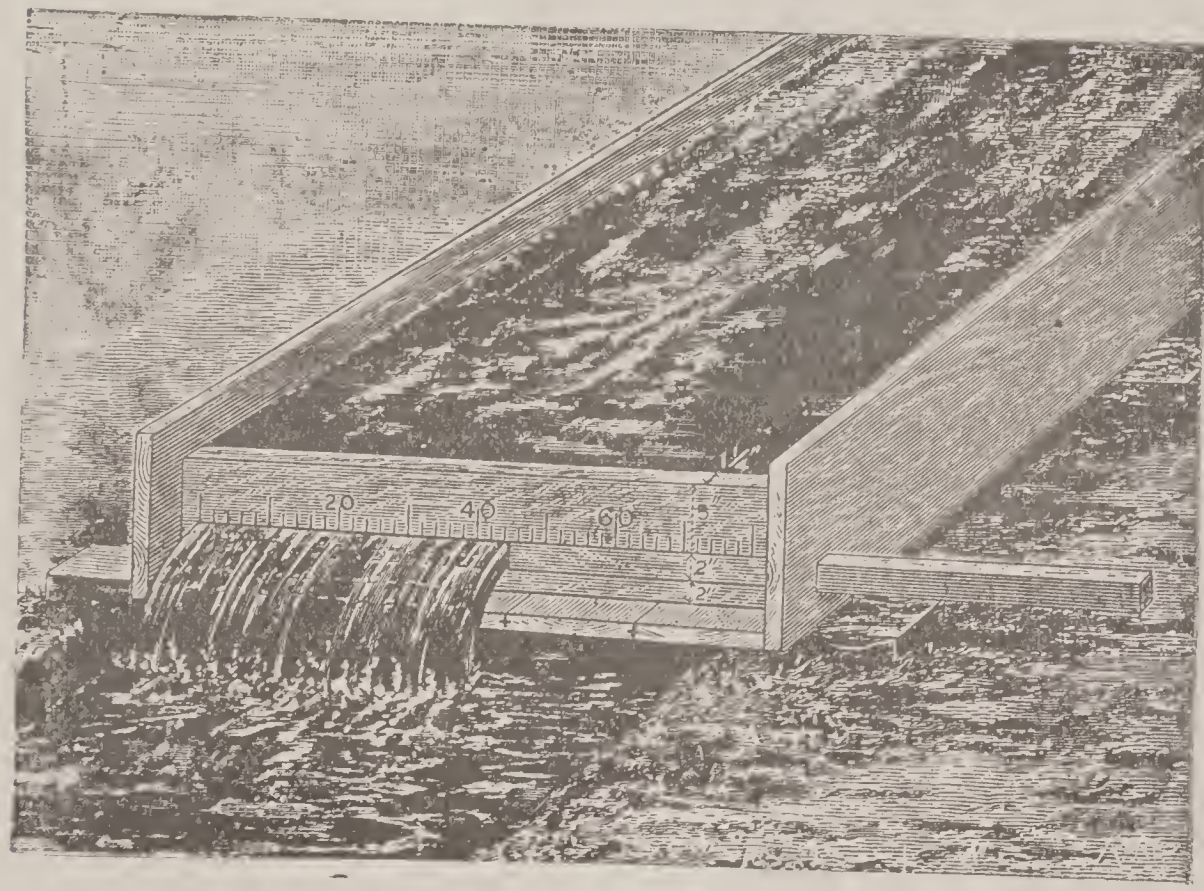
By permission of the Pelton Water Wheel Co., 121 Main street, San Francisco, I herewith reproduce from the sixth edition of their catalogue a cut and description of Miner's inch measurement for measuring the water of a stream by a Weir dam, and the table by which the flow can be interpreted into cubic feet per minute. Those desiring to use water as a means of power would do well to consult their catalogue.

Giving Cubic Feet of Water per minute, that will flow over a Weir one inch wide and from $\frac{1}{8}$ to $20\frac{7}{8}$ inches deep.

INCHES.		⅛	¼	⅜	½	⅝	¾	⅞
0.....	.00	.01	.05	.09	.14	.19	.26	.32
1.....	.40	.47	.55	.64	.73	.82	.92	1.02
2.....	1.13	1.23	1.35	1.46	1.58	1.70	1.82	1.95
3.....	2.07	2.21	2.34	2.48	2.61	2.76	2.90	3.05
4.....	3.20	3.35	3.50	3.66	3.81	3.97	4.14	4.30
5.....	4.47	4.64	4.81	4.98	5.15	5.33	5.51	5.69
6.....	5.87	6.06	6.25	6.44	6.62	6.82	7.01	7.21
7.....	7.40	7.60	7.80	8.01	8.21	8.42	8.63	8.83
8.....	9.05	9.26	9.47	9.69	9.91	10.13	10.35	10.57
9.....	10.80	11.02	11.25	11.48	11.71	11.94	12.17	12.41
10.....	12.64	12.88	13.12	13.36	13.60	13.85	14.09	14.34
11.....	14.59	14.84	15.09	15.34	15.59	15.85	16.11	16.36
12.....	16.62	16.88	17.15	17.41	17.67	17.94	18.21	18.47
13.....	18.74	19.01	19.29	19.56	19.84	20.11	20.39	20.67
14.....	20.95	21.23	21.51	21.80	22.08	22.37	22.65	22.94
15.....	23.23	23.52	23.82	24.11	24.40	24.70	25.00	25.30
16.....	25.60	25.90	26.20	26.50	26.80	27.11	27.42	27.72
17.....	28.03	28.34	28.65	28.97	29.28	29.59	29.91	30.22
18.....	30.54	30.86	31.18	31.50	31.82	32.15	32.47	32.80
19.....	33.12	33.45	33.78	34.11	34.44	34.77	35.10	35.44
20.....	35.77	36.11	36.45	36.78	37.12	37.46	37.80	38.15

Suppose the Weir to be 66 inches long, and the depth of water on it to be $11\frac{5}{8}$ inches. Follow down the left hand

column of the figures in the table until you come to 11 inches. Then run across the table on a line with the 11, until under $\frac{5}{8}$ on top line and you will find 15.85. This multiplied by 66, the length of Weir, gives 1046.10, the number of cubic feet of water passing per minute.



The term "miner's inch" is of California origin, and not known or used in any other locality, it being a method of measurement adopted by the various ditch companies in disposing of water to their customers. The term is more or less indefinite, for the reason that the water companies do not all use the same head above the center of the aperture, and the inch varies from 1.36 to 1.73 cubic feet per minute each, but the most common measurement is through an aperture 2 inches high and whatever length is required, and through a plank $1\frac{1}{4}$ inches thick, as shown in print. The lower edge of the aperture should be 2 inches above the bottom of the measuring box, and the plank 5 inches high above the aperture, thus making a 6-inch head above the center of the stream. Each square inch of this opening represents a miner's inch, which is equal to a flow of $1\frac{1}{2}$. cubic feet per minute.

ASSAY TON WEIGHTS.

The Assay Ton Weights is a system made up from a comparison of the Avoirdupois, Troy and Gramme Weights, and will be found extremely simple and useful, saving a vast amount of calculation and labor.

The unit of the system is the assay ton=29,166 grammes. Its derivation will be seen at a glance.

1 ℔. Avoirdupois=7,000 Troy grains.

2,000 ℔s.=1 ton.

2,000×7,000=14,000,000 Troy grains, in one ton Avoirdupois.

480 Troy grains=1 oz. Troy.

14,000,000÷480=29,166 Troy ozs. in 2,000 ℔s. Avoirdupois.

There are 29,166 milligrammes in one assay ton (A. T.); hence 2,000 ℔s. is to A. T. as 1 oz. Troy is to 1 milligramme.

Therefore, if 1 A. T. of ore assays 1 milligramme of gold or silver, the ton contains 1 ounce Troy.

CONSTRUCTING THE A. T. WITH GRAIN WEIGHTS.

In constructing the A. T. on the grain system, it is only necessary to remember that in one ton of 2000 pounds there are 29,166 Troy ounces. Consequently, if we take 291.66 grains of the ore pulp for the assay, each bead point in weight obtained in a one-hundredth part of a grain represents one ounce of metal in a real ton of the ore. This is very convenient where the ore contains much metal. But, for very low grade ores, it is better to double the amount (291.66) and take 583.32 grains of the prepared pulp for an assay. In that case, each bead point in weight will represent one-half ounce of metal to the real ton of the ore, in either gold or silver. These weights can be prepared and accurately determined out of a peice of lead, and the A. T. doubled, halved, or quartered, as desired.

By permission of the Pelton Water Wheel Co., 121 Main street, San Francisco, I herewith reproduce from the sixth edition of their catalogue a cut and description of Miner's inch measurement for measuring the water of a stream by a Weir dam, and the table by which the flow can be interpreted into cubic feet per minute. Those desiring to use water as a means of power would do well to consult their catalogue.

In the foregoing work I have followed C. H. Aaron more largely than other authors for the reason that I consider his methods far the best of all, for practical work.

Books consulted in the preparation of this work:

Joseph Le Conte's Geology.
F. E. Thorpe's Chemistry.
Bowman's Chemistry.
Thomas Bailey's Chemistry.
James D. Dana's Mineralogy.
Mining and Scientific Press.
Mitchell's Manual on Assaying.
H. Van F. Furman on Assaying.
Francis Sutton on Volumetric Analysis.
J. S. Phillips' Metallurgists' Companion.
Joshua Trimmer's Analysis of Minerals
J. M. Craft's Qualitative Analysis.

The important and highly remunerative industry of mining has, during the last few years, been prosecuted in the Northwest with greatly renewed energy and vigor.

The renewed activity in the search for and development of these great sources of wealth is due to many causes. The constantly appreciating value of gold is one cause of this activity, it being apparent, under the present economic conditions, that though other products may fall in price from over-production, the production of gold cannot be overdone. The low price of labor, the extension of steam transportation and the highly improved methods for the reduction and treatment of ores, are other important factors in the new development of the mining industry.

It is evident that the renewed energy has but now begun and that it will continue to grow until the mining industry will be one of paramount importance in the Northwest, engaging the industry of great numbers of our people, and calling for the professional employment of a great amount of skilled superintendence and knowledge.

In view of the above well-known facts, the Portland School of Mines, Engineering and Assaying has been established, in order to give an opportunity to the young men and women of the Northwest to prepare themselves for remunerative employment in all the different mining activities that promise a profitable field of professional labor.

TESTIMONIAL LETTERS.

We herewith submit a few testimonial letters from our students, some of whom are holding positions of trust and responsibility. These letters speak for themselves:

Walla Walla, Wash., May 17, 1897.

J. H. Fisk, Esq., Portland, Oregon:

Dear Sir—Having taken lessons in assaying under your instructions, I beg leave to say that I can cheerfully recommend you as a teacher in all that class of business, for the reason that you are better acquainted with the rocks, ores and mineral formations of this immediate country than any other professor could be at the present time.

Very respectfully,

J. P. ISAACS,
Assayer and Ore Sampler.

Bernard Bay, Alaska, July 12, 1897.

J. H. Fisk, Portland School of Mines:

Dear Sir—Having pursued a course of study in mining, assaying and testing of ores under your instructions, I beg to say that I have found the methods used by you of great value to me in my practical experience as an assayer, and can heartily recommend the same to all others desiring information in the same line of business.

Respectfully,

A. H. PETTIT,
Assayer for the P.-A. G. & S. M. Co.

C. M. COOK,
Assayer, Stevenson, Wash.

Stevenson, Wash., May 24, 1897.

J. H. Fisk, Esq., Portland School of Mines, Portland, Or.:

Dear Sir—Having attended your lectures and taken a course of study under your instruction the past winter, it affords me pleasure to state that, in practical application, I have found your formulas for testing, treating and assaying ores of great value, and their efficiency unexcelled by any authors on assaying.

I would cordially recommend the course of study and lectures under your instruction and illustration to all desiring practical information in that direction.

Respectfully,
C. M. COOK,
Assayer.

Portland, Or., May 13, 1897.

Mr. J. H. Fisk, Portland School of Mines:

Dear Sir—We, the undersigned, late students of yours in assaying and testing ores, beg to contribute our testimony to your ability and faithful services as a teacher, and unhesitatingly and unqualifiedly recommend your methods to all others.

A. E. BORTHWICK.
MISS I. SEDGWICK.
ALBERT J. FROELICH.
H. A. BROWER.
J. GUSTAFSON.
OSCAR STARR.
MISS M. STARR.
MRS. L. M. COBURN.
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On sending samples by mail, mark your name on the outside, and mark each sample distinctly, and in a separate letter give full instructions. Write your name and address plainly, and send money for each assay by postoffice order or with the package of ore. If money is not sent for assaying, returns will be made by express, C. O. D.

204½ WASHINGTON STREET, PORTLAND, OR.

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